8.0. SOIL RESOURCES

This section briefly explains the soil resources supporting biological production in riparian and upland areas throughout Newaukum Creek basin. Basic soil properties are relevant to habitats and key ecological processes throughout the basin. Detailed soil maps are available, but exceed the scope of this report.

Soil develops at the surface of the earth as a result of complex and interrelated processes that occur at the interface between the land and atmosphere. These processes include weathering and breakdown of the geologic parent material, formation of secondary minerals, incorporation of organic matter, and movement of soil constituents by water moving through the soil column. In the Newaukum Creek watershed, soil development has been largely controlled by two factors; the parent material (geologic substrate) and soil drainage (surface and shallow subsurface hydrology). Elevation also affects soil development because it exerts the primary control on temperature and precipitation variations across the watershed.

Most of the soils in the Newaukum basin are formed from three types of parent material. These are: volcanic bedrock, glacial deposits, and the Osceola mudflow. In areas with persistent sanding water (see drainage discussion below) sufficient vegetative matter can accumulate so that soil develop entirely in this surficial organic material. Specific soil series are associated with each of these parent materials are presented in Table 6.

Table 6. Parent materials and associated soil types in the Newaukum Creek basin.

Parent Material	Soil Name	Cumulative Percentage
Glacial Deposits	Indianola loamy fine sand Scamman silt loam Everett gravelly sandy loam Barneston gravelly coarse sandy loam Ragnar fine sandy loam Neilton very gravelly loamy sand Winston Loam Alderwood Gravelly Sandy Loam Norma loam	44.9%
Osceola Mudflow	Buckley silt loam Lemlo silt loam	31.7%
Volcanic Bedrock	Pitcher sandy loam Nagrom Sandy Loam Ovall gravelly loam Christoff sandy loam Littlejohn gravelly sandy loam Ogarty gravelly loam Kanaskat gravelly sandy loam	12.5%
Organic Material	Shalcar muck Seattle muck Tukwila muck	4.1%

Much of the Newaukum Creek watershed is located on the broad, low gradient surface of the Enumclaw plateau. Much of soil parent material on the Plateau is fine-grained and very compact so that it is relatively impervious. This low permeability, combined with the almost level topography combined to create broad areas where (prior to construction of the current drainage system) standing water or soil saturation is present for much of the year. These areas formed the extensive wetlands that characterized the pre-development Plateau (Fig. 24). As a result the SCS classified 49% percent of the soils in the basin as either poorly drained or very poorly drained (SCS, 1973, 1992). Soil development in these areas was strongly affected by the extended periods of soil saturation and associated anaerobic (low oxygen) conditions. Decomposition of plant matter was inhibited by the lack of oxygen so thick organic layers often accumulated above mineral soil. The low gradient and common areas of standing water also locally lead to deposition of fine-grained mineral sediments above the in-place parent material. With the installation of extensive drainage systems many areas that had wet or saturated soils under natural conditions are now in agricultural production.

The texture of the Osceola is somewhat finer than typical till deposits. The mudflow has some clay component which originated as a product of chemical alteration of volcanic rocks in-place on the mountain. A high clay content typically means lower permeability, higher water-holding capacity, and higher cation exchange capacity (CEC). Soil developed on the mudflow deposits tend to be wet both due to the low permeability of the soil and the flat topography on the surface of the mudflow.

Till is generally gravelly silty sand. Where weathered and disaggregated (nearer the top of the soil horizon) soil developed on till tends to be well drained. The C horizon of till soils however becomes very impermeable due to the due to compaction by glacial loading and maybe some post-glacial chemical cementation. As a result there is often a seasonal water table perched on top of the intact till. With little clay or organic content till soils tend to have a relatively low CEC.

9.0. PLANTS AND ANIMALS – THE BIOTIC COMMUNITY

In this section, we characterize the basic structure, composition and distribution of key organisms that dominate aquatic, riparian, and terrestrial (upland) communities of the Newaukum basin. Biotic communities can strongly influence ecosystem processes. Their influence depends on the types of species present, their functional characteristics, relative abundances, and the nature of their interactions (Chapin et al. 2003). After characterizing special status species (Section 9.1, we provide a broader perspective of the plants and animals that compose the Newaukum Creek basin (Sections 9.2-9.6). We use a community-based approach to describe important groups of plants and animals, and explain their individual taxonomy, life history, trophic position (in other words, their place in the food web) or ecological attributes.

9.1. SPECIAL STATUS WILDLIFE SPECIES

This section summarizes the basic life history characteristics, distribution, and population abundance (if known) of 16 ‘special status’ wildlife species occurring in the Newaukum Creek basin (Table 7). Our rationale was that these species play a pivotal role in management actions, so a basic understanding of their life history, status, distribution, and biological context is warranted. We include species with special designation at the federal, Washington State, and/or King County level. Most special status species are fish and birds. None of the rare plant species that occur in King County are known to be present in the Newaukum Creek Basin (WNHP 2006). We describe the life history requirements of the 16 individual species for simplicity and practicality. However, we emphasize that efforts to assist individual species must be firmly embedded in an understanding of their context in the broader ecosystem, including population and community-scale interactions. Characterizations of fish species address most (or all) of the factors explained in Table 8. Please note that many additional species are described in Sections 9.2-9.6. and that Newaukum Creek basin also contains Special Status Lands (Fig. 37)

Table 7. Special Status Wildlife Species that may be using breeding or foraging habitat in Newaukum Creek basin or have likely been extirpated.

Common Name	Scientific Name	Status[†]
Chinook (king) salmon	*Oncorhynchus tshawytscha*	FT
Bull trout	*Salvelinus confluentus*	FT
Rainbow (steelhead) trout	*O. mykiss*	Pending FT
Bald eagle	*Haliaeetus leucocephalus*	FT, ST, KCC
Spotted owl	*Strix occidentalis*	FT (extirpated)
Marbled murrelet	*Brachyramphus marmoratus*	FT (extirpated)
Vaux's swift	*Chaetura vauxi*	SC, KCC
Pileated woodpecker	*Dryocopus pileatus*	SC, KCC
Osprey	*Pandion haliaetus*	KCC
Great blue heron	*Ardea herodius*	KCC
Red-tailed hawk	*Buteo jamaicensis*	KCC
Western toad	*Bufo boreas*	FCo, SC, KCC
Tailed frog	*Ascaphus truei*	FCo
Long-eared myotis	*Myotis evotis*	FCo
Long-legged myotis	*Myotis volans*	FCo
Pacific Townsend's big-eared bat	*Corynorhinus townsendii townsendii*	FCo, SC, KCC

[†] FT = Federal Threatened; ST = State Threatened; FCo = Federal Species of Concern; SC = State Candidate; SS = State Sensitive; KCC = Protected under King County Code

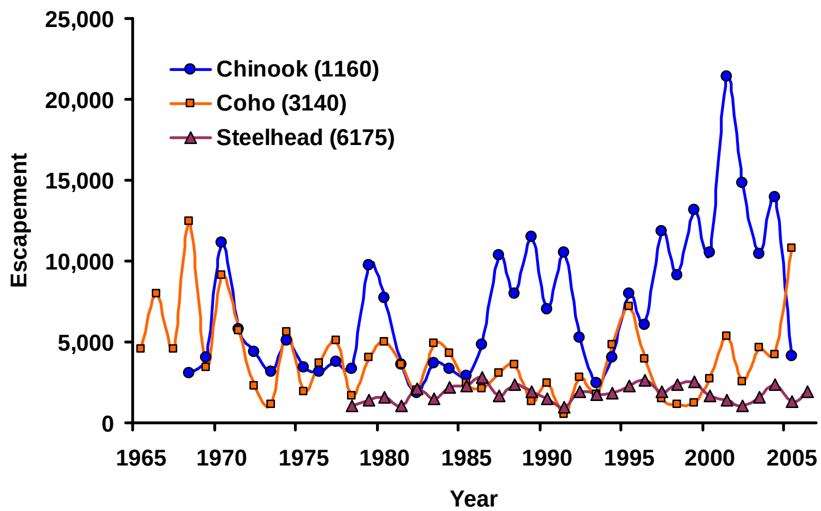
Figure 37. Map of special status lands.

PLEASE SEE SEPARATE FILE

9.1.1. Chinook salmon

Chinook salmon are protected as a threatened species under the Endangered Species Act, and are a primary focus of basin recovery plans (WRIA 9 Steering Committee, 2005). The Duwamish/Green River Chinook salmon population is a native stock (# 1160) with composite production, with total escapement ranging from 2,476 to 21,402 (Fig.37). This is managed as a 'integrated' stock by the Washington Department of Fish and Wildlife. Historical run sizes apparently peaked upwards of 37,000 individuals (WRIA 9 Steering Committee, 2005). Roughly 1,700 chinook now spawn naturally in the river (e.g., ~5% of the estimated historical maximum run size).

Figure 38. Escapement estimates for Green River chinook†, coho salmon †† and steelhead ††† (Washington Department of Fish and Wildlife 2007; stock identities are indicated in parentheses)

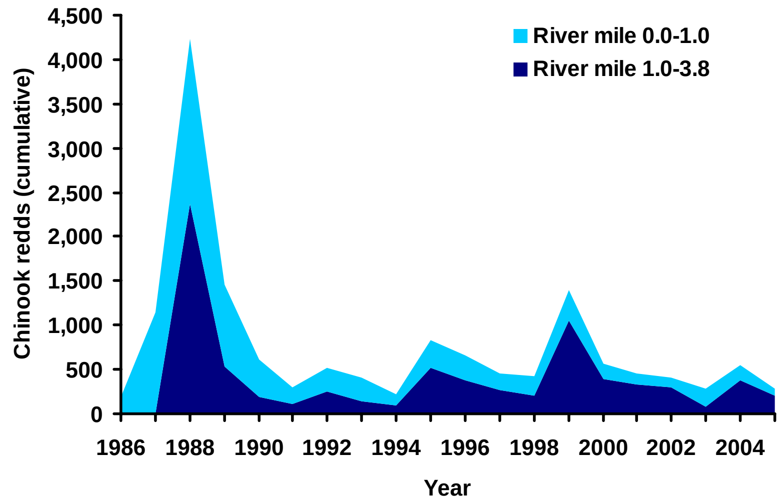


† Total escapement estimates for chinook are based on redd counts in the mainstem Green River from RM 35.0 to 41.5 and from RM 41.5 to 43.0, and in Newaukum Creek from RM 0.0 to 3.9. Estimates from 1997 on are based on results from WDFW mark-recapture studies conducted from 2000 to 2002.
†† Escapement estimates for coho are the sums of cumulative fish*days values for Hill (WRIA 09.0051), Newaukum (09.0114), Spring (09.0119), Cress (09.0121A), and North Fork.Newaukum (09.0122) creeks indices.
††† Total escapement estimates for steelhead are based on cumulative redd counts in all mainstem spawning areas (RM 26.4 to 59.9) and in index reaches in Soos and Newaukum creeks totaling 12 miles.

The established spawning aggregation in Newaukum Creek is thought to represent a valuable component of the Duwamish/Green River population. It diversifies the larger population and receives many of the naturally spawning Chinook adults entering the Green River (WRIA 9 Steering Committee, 2005). On average, 45% of the spawning Chinook adults in Newuakum Creek are of known hatchery origin (ranging from 15 to 79% from 1989-1997; Kerwin and Nelson 2005). As a result, the system is thought to contribute substantially to the productivity of the Duwamish/Green River stock (WRIA 9 Steering Committee, 2005). Genetic analysis indicates natural spawners in Newaukum Creek are indistinguishable from those in Soos Creek Hatchery. This is attributable to significant gene flow between naturally spawning fish and those originating from the hatchery.

Spawning occurs in the fall, primarily in the Ravine. In general, adults salmon forage at sea for 2-4+ years prior to returning to spawn in natal streams (Quinn 2005). Duwamish/Green River mature adults begin migrating upstream in September and quickly commence spawning, which lasts through the end of November. Peak returns now occurs in early October rather than late October, presumably due to hatchery practices (WRIA 9 Steering Committee, 2005). Most spawning is thought to take place in the lower two to four miles of Newaukum Creek, but extends at least eight miles from the confluence with the Green River to the 244th St. intersection (Goldstein 1982; Boehm 1999). Redd densities vary among locations and years (Fig. 39)[41]. Eggs incubate in spawning gravels through the winter and hatch in the spring.

Figure 39. Cumulative number of chinook redds counted in two index reaches in Newaukum Creek (Washington Department of Fish and Wildlife). This is a stacked area graph. Note that redd counts in RM 1.0-3.8 begin in 1988.



Juvenile Chinook inhabiting Newaukum Creek are presumed to exhibit similar life histories to those in the greater population, though this has not been verified. Five juvenile life history trajectories are presumed to have existed in the Duwamish/Green River system prior to extensive development; their loss may have coincided with steep declines in productive estuarine habitats and construction of the Howard Hanson dam. Only ‘estuarine-reared fry’ and ‘marine-direct fingerlings’, which originate from ‘fall’ Chinook salmon, are now common (WRIA 9 Steering Committee, 2005). Resulting juveniles are ‘ocean-type’, migrating downstream to estuaries shortly after emergence. ‘Estuarine-reared fry’ primarily originate from naturally spawning fish and occupy mainstem and side channel habitats, migrating to the estuary or nearshore after a few days to weeks in freshwater or at 45-70 mm in length. They are present in estuary from April to May and move offshore in May and June, exhibiting the longest estuary residence time of any life history type remaining in the system. In contrast, ‘marine-direct fingerlings’ apparently originate from both natural and hatchery-spawning fish. These fingerlings

[41] Note that continuous surveys are necessary for accurate evaluations of the distribution of spawning in space and time. Observations from fixed index reaches do not necessarily reflect temporal trends in redd abundance at the basin-scale, as fish may be spawning in different locations (outside the index reaches, for example).

are likely more reliant on freshwater habitats than estuary-rearing fry. Fingerlings linger in natal streams for weeks or months until migrating to the estuary and nearshore at roughly 70 mm in length, presumably *en masse*. They remain in the estuary for roughly two weeks.

Existing juvenile life history types probably rely more heavily on the availability of oversummering habitats than overwintering habitat, because they leave Newaukum Creek prior to winter. Summer feeding (rearing) habitat for juvenile Chinook in Newaukum Creek now exists primarily downstream from RM 10, near where Newaukum Creek crosses 416th. Chinook juveniles have been observed rearing between RM 8-10; though spawning in this section is uncommon (R. Fritz, *pers. comm.*). Juvenile Chinook originating from the Green River mainstem could plausibly move into Newaukum Creek and rear during the summer, as well. A single chinook salmon juvenile was caught in a smolt trap in Big Spring Creek in the spring of 2005[42].

Optimum stream temperatures for Chinook salmon vary among life stages (see Richter and Kolmes 2005 for review and primary references). Daily maximum temperatures exceeding 20˚C represent thermal barriers to migrating spawners. Spawning generally occurs only when temperatures are below 14.5˚C. Incubating embryos and alevins survive best at temperatures below 9˚C whereas temperatures of 13.9 to 19.4˚C result in severe mortality. Optimal temperatures for juvenile rearing are approximately 15˚C, ranging from 12-17˚C depending on food availability. High juvenile mortality results when daily maximum temperatures exceed 24-26˚C. Smoltification is impaired at temperatures above 17˚C, but this varies widely among studies.

Recent surveys estimated the density of juvenile Chinook in the lower Ravine to range from 0.002 to 0.008 fish m^{-2} among reaches in mid-June (TetraTech, Inc., 2005). In late July of 2006, Chinook represented 1-8% of the total fish abundance (among reaches), ranging from 30 to 120 mm (not including a 180 mm outlier) in total length. Whereas 83% used slow water habitats in one reach, only 33% were in slow water in another reach; the rest (67%) were in fast water.

Habitat connectivity is a potential obstacle for spawning migrations near the mouth of Newaukum Creek[43]. Specifically, upstream migrations by spawning salmon are sometimes blocked or restricted where Newaukum Creek runs across an alluvial fan at the confluence with the Green River mainstem. This potential passage barrier is usually attributed to 1) downcutting by the Green River mainstem; 2) increased downwelling through the alluvial fan in response to the enhanced hydraulic gradient; and 3) deposition of transported sediment several sources through Newaukum Creek. Upstream migration is presumed to be limited by a steep cascade in the Boise Ridge Reach (Fig. 22) (Williams et al. 1975).

9.1.2. Bull trout

Bull trout is under federal protection as a threatened species (Table 7). No bull trout have been detected in Newaukum Creek, despite numerous surveys (See Washington State Salmonid Stock Inventory – Bull Trout/Dolly Varden, October 2004).

[42] http://www.midsoundfisheries.org/smolttrap.html

[43] Mid-Sound Fisheries Enhancement Group is conducting a comprehensive assessment of fish passage barriers in Newaukum Creek (T. Fields, *pers. comm.*). It is expected that juvenile barriers are more common than barriers to spawning adults.

9.1.3. Steelhead trout

Newaukum Creek contains a native winter (ocean-maturing) steelhead trout stock (# 6175) (Table 7), which are used in hatchery programs at Soos Creek and Icy Creek. Naturally-spawned Puget Sound steelhead (both summer and winter runs) are protected as threatened species under the ESA. However, Green River steelhead are thought to have a low risk of extinction, relative to other populations throughout Puget Sound. Winter steelhead of hatchery origin (mostly from Chambers Creek) are also present, but are assumed to contribute little gene flow to the native stocks because they spawn at different times[44]. Winter steelhead are closely related to those from the Cedar, White, Puyallup, and Snohomish basins (Phelps et al. 1997). A total of 558 spawners were passed above Howard Hanson dam from 1992-2000, ranging in number from seven fish in 1997 to 133 fish in 1996 (WDFW, 2007). Average escapement estimates for the Green River were 2,249 fish from 1994 to 1998 and 1,827 fish from 1999-2004.

Newaukum Creek provides valuable spawning areas for winter steelhead, including Big Spring Creek and most of the mainstem – but especially between RM 10 and 11 (Rob Fritz, *pers. comm.*). They may also spawn in portions of Watercress Creek. Surveys in 2005 found 17 steelhead redds across four reaches (totaling 5.4 miles) downstream from RM 8.7; 16 of 17 redds were found from RM 1-3.8 (WDFW, 2007).

In general, steelhead return to spawn in natal streams (potentially more than once) after foraging at sea for 1-3 years (Quinn 2005). Winter steelhead vary from Pacific salmon in that they reach an advanced stage of maturity when they enter streams early in the year and quickly commence spawning (Quinn 2005). This occurs roughly from February through June in the Green River system. They bury relatively small eggs in gravels while stream temperatures are climbing. Fry emerge in late spring and earlier summer (Quinn 2005).

The steelhead trout is currently considered the same species as rainbow trout (*O. mykiss*); the steelhead is the anadromous form, whereas the rainbow trout is the freshwater form (Quinn 2005). However, the distinction between the two is the subject of ongoing investigation. Newaukum Creek hosts rainbow trout (and juvenile steelhead) throughout the year. Steelhead spend 1-3 years feeding and growing in freshwater. Over-summering habitats are distributed throughout the basin, especially the North Fork, South Fork, Big Spring Creek, and Watercress Creek. Overwintering habitats are more narrowly distributed due to the limited availability of complex refugia.

Optimum stream temperatures range widely among steelhead life stages (see review by Richter and Kolmes 2005). Spawning migrations are blocked by temperatures over 21˚C. Spawning occurs when daily temperatures average roughly 10-13˚C. During incubation, optimal temperatures are below 9˚C and the daily maximum should never exceed 14.5˚C. Juvenile steelhead grow fastest at 14-15˚C, but 16-17˚C also appears acceptable. The 7-day annual maximum temperature should not exceed 20.5˚C.

Recent surveys estimated the density of juvenile steelhead in the lower Ravine to range from 0.013 to 0.021 fish m^{-2} among reaches (mid-June 2005, TetraTech, Inc.). In late July 2006, rainbow trout represented 49-67% of total fish abundance (among reaches), ranging from 20-

[44] A non-native, severely depressed hatchery stock (Skamania; since 1965) of summer steelhead (# 6168) is present in the Green River, but thought to be absent from Newaukum Creek. A self-sustaining population may exist, but this is undetermined (K. Lakey, WDFW, *pers. comm.*).

280 mm in total length. Most occurred in ‘fast’ (i.e., from 43 to 50%) and ‘slow’ water units (i.e., 25-50% among reaches), rather than in backwaters, side channels, or near wood (though these are relatively scarce).

9.1.4. Bald eagle

Bald eagles nest in large, open-limb trees within one mile of large bodies of water or on cliffs and feed primarily on fish (Scott 1987) (Table 7). Priority Habitats and Species (PHS) data from Washington Department of Fish and Wildlife (see WDFW 2006) reports that a bald eagle nest site was located in the Buckley quadrant in 2000, but not thereafter. The nest was in a small grove of black cottonwoods adjacent to Newaukum Creek in an area surrounded by agricultural fields. No other bald eagle nests are known in the Newaukum Creek basin, presumably because of the lack of mature forest stands near large water bodies.

9.1.5. Spotted owl

The lack of old-growth forest in Newaukum Creek basin precludes old-growth-dependent birds such as spotted owls from nesting here (Table 7). However, this species may be nesting in the upper Green River Watershed and could potentially use the Forest Production District (FPD) in Newaukum Creek basin as part of their travel corridor. If so, their use of this forest as a stop-over during daily and annual migrations is expected to be extremely limited because of a general lack of mature forest in the region.

9.1.6. Marbled murrelet

The upland forests of the Newaukum Creek would have provided habitat for Marbled murrelets, but this species is thought to be extirpated basin by the loss of old-growth forests (Table 7). As with the spotted owl, this species may be nesting in the upper Green River Watershed and may use the Forest Production District (FPD) in Newaukum Creek Basin as part of its travel corridor.

9.1.7. Vaux’s Swift

Vaux’s Swift nests in mature forest within hollow trees and cavities created by woodpeckers and they forage over open areas and water (Table 7). This species is a confirmed breeder in the basin near Enumclaw. Vaux’s Swifts are positively associated with old-growth forest (Bull and Hohmann 1993) and may be the only diurnal bird that depends on old-growth for its continued survival (Manuwal 1991). Nest sites are likely to be a critical limiting resource for this species, which are colony nesters (Manuwal 1991). Only large-diameter hollow trees can accommodate swifts (Bull and Blumton 1997). Suitable roost trees are most likely to occur in old-growth stands (Bull 1991). The species occasionally nests in chimneys, though populations cannot be maintained without mature forests for nesting. The small amount of open water (i.e., foraging habitat) in this basin is likely a secondary limiting factor for Vaux’s swifts.

9.1.8. Pileated Woodpecker

The Pileated Woodpecker is the largest woodpecker species in Washington (Scott 1987), and nests and forages in mature and second-growth forests (Table 7). The optimal habitat for Pileated Woodpeckers is conifer forest with at least two canopy layers, the uppermost being 80 to 100 feet in height (Bull 1987). Snags, down logs, and stumps are key components of nesting and foraging habitat (in which woodpeckers feed on carpenter ants [*Camponotus*]; Scott 1987) for this species, which annually excavates a new nesting cavity in large snags or partially decayed live trees (Mellen et al. 1992, Bull and Jackson 1995, Aubry and Raley 2002b). Other species depend on these woodpeckers for the creation of nesting cavities. Pileated Woodpeckers may thus be considered “ecological engineers” (Jones et al. 1994) because they are the only species able to excavate large cavities in hard snags and decadent live trees, and a wide array of other bird and mammals species use their cavities. This species is possibly nesting in the basin near the Green River.

9.1.9. Osprey

Osprey are not known to nest in the Newaukum Creek basin (Table 7). Osprey are closely associated with rivers, estuaries, lakes, and other large bodies of water, and they feed over open water almost exclusively on fish. Osprey tend to select dead snags or dead-top trees that are higher than the surrounding canopy, but they will also nest on platforms and power poles. Nest trees frequently occur in flooded riparian zones and wetlands created by beavers. We speculate that reductions in beaver populations have likely affected the availability of preferred osprey nest sites, as has been documented elsewhere (Ewins 1997).

9.1.10. Great Blue Heron

Currently, Great Blue Herons are not known to breed in the Newaukum Creek basin (Table 7). Herons prey on fish, amphibians and small, field-dwelling mammals, and breed in colonies called rookeries; their nests are built in tall trees. The Breeding Bird Atlas reports this species is observed in the basin during breeding season. No actual breeding behavior has been observed.

9.1.11. Red-tailed hawk

Red-tailed hawks are known to breed in the Newaukum Creek basin. This species, which is somewhat ubiquitous in King County, hunts over open fields, road shoulders, and utility right-of-ways (Table 7). Their primary prey is small mammals, which are abundant in the Newaukum Creek basin. Nests are usually large platforms made out of sticks placed in a tall hardwood tree (Seattle Audubon Society 2006), however they may nest in conifers as well (Richter, *pers. comm.*). The scattered small stands of forest throughout the Plateau in addition to the forest of the ravine and FPD likely provide ample nesting opportunities for this species.

9.1.12. Western toad

The western toad has apparently disappeared or declined significantly in many areas of Washington, but it is still widespread beyond the Puget Trough and locally abundant in some areas within King County (Table 7). For instance, the western toad has been confirmed in only 21 of 86 historical sites in the Puget Trough Ecoregion, since 1980 (Hallock and McAllister 2005). Several of these remaining populations are now extirpated, including the population at Beaver Lake in King County (Hallock and McAllister 2005). It is possible the western toad is present in the forest of the Upper Basin and breeds in the forested wetlands found in the Newaukum Creek basin.

The basic life history of the western toad is summarized by Leonard et al. (1993). The western toad breeds in permanent water wetlands and is found in uplands forests and field outside of breeding season. The breeding season lasts from spring to early summer, depending on elevation. Egg masses resemble long strings or shoelaces strewn across the bottom of floodplain pools or wetlands and may contain 12,000 eggs. Embryos develop into tadpoles in only three to 10 days, which graze on detritus, filamentous green algae or scavenge carcasses. Metamorphosis occurs at the end of their first summer. Western toads are particularly sensitive to the loss of wetland habitats.

9.1.13. Tailed frog

The current status and distribution of the tailed frog in Newaukum Creek has not been evaluated (Table 7). The tailed frog is generally limited to the mid to higher elevation mountain streams in mature forests (Dvornich et al. 1997; Leonard et al. 1993) but could potentially occur in clean, rapidly flowing streams in lower elevations of the upper basin as well (but not lakes or ponds).

Life history of the tailed frog is summarized by Leonard et al. (1993). Mating occurs in fall, and fertilized eggs are attached to the undersides of large rocks in the stream. Embryos hatch within six weeks and commence grazing on biofilms covering instream rocks. Most tadpole activity occurs at night, presumably to reduce risk of predation by fish or Pacific Giant salamanders. Tadpoles metamorphose in one to four years, depending on elevation, and mature within six more years, depending on the length of summers. Adult tailed frogs primarily forage on insects from riparian areas at night (Leonard et al. 1993).

9.1.14. Long-eared myotis

Long-eared myotis (bats) roost in caves, buildings, and trees and they forage over water and in open areas (Table 7). The lack of old-growth trees and snags as well as lack of caves in this basin severely limit the number of potential maternity roosts for the large maternity colonies that Myotis bats commonly form in spring (Christy and West 1993). There are no known bat maternity colonies or hibernating sites in the basin, nor are there any known day roosts. However, there is no comprehensive survey information available for bats in the basin, so it is possible that any of these three bat species could be present. The status of this species in the basin is unknown.

9.1.15. Long-legged myotis

Long-legged myotis are usually found along forest edges and among trees; summer day roosts include buildings, crevices in rock cliffs, and under tree bark; maternity colonies have been found in fissures in the ground, attics, and under tree bark (Table 7). Additional details are in the preceding section. The status of this species in the basin is unknown, but it is presumed to be absent.

9.1.16. Pacific Townsend’s big-eared bat

The Pacific Townsend’s big-eared bat establishes breeding and hibernation colonies in abandoned mines, caves, and buildings (Table 7). The status of this species in the basin is unknown, but it is presumed to be absent.

9.2. STREAM COMMUNITIES

We describe the species comprising the aquatic communities of the Newaukum basin according to where they typically occur – streams or wetlands. Within each of these categories, we group species according to their trophic level. Our rationale is that this approach will shed light on the ecological – not just taxonomic – structure of the community. Species are grouped with related taxa within trophic levels. In most cases, we explain their status, life history, and distribution within the Newaukum Creek basin. For brevity, we explain only a limited number of competitive interactions (e.g, mutualism, competition, predation, etc) between species. Our characterization of stream and wetland communities is clearly biased toward fish, which have particular political and social relevance.

The biological condition of Newaukum Creek is mostly fair, ranging to good/excellent, according to recent estimates of the Benthic Index of Biotic Integrity (B-IBI; Karr 1998) EVS method (Fig. 41, McElligott and Holt 2004, McElligott et al. 2005). The average total number of macroinvertebrate taxa was 33.8 (± 7.0 SD), with 19.2 (± 5.0 SD) in the Ephemeroptera-Plecoptera-Trichoptera orders. Generally, B-IBI scores are divided into qualitative intervals representing, 'very poor' (10-16), 'poor'(18-26), 'fair'(28-36), 'good' (38-44), and 'excellent' (46-50). Average B-IBI scores have gradually improved in the past few years, climbing from 30.4 (±8.3 SD) in 2002, to 33.3 (±9.2 SD) in 2003, and finally to 37.4 (±5.6 SD) in 2005[45]. In 2003, Newaukum Creek scored 3.7 (± 0.8 SD) on the Hilsenhoff Biotic Index scale (1-10), which discriminates between pollution intolerant communities (i.e., low scores) and those that tolerate pollution (i.e., high scores) (McElligott et al. 2005). Samples were also collected in 2004 where the North Fork intersects 292nd SE and where the mainstem crosses the Veazie-Cumberland Road[46] (R. Fritz, *unpublished data*). Scores and sampling locations are included in Fig. 41.

9.2.1 Aquatic Primary Producers and Herbivores

Aquatic primary production plays in important role in supporting the biological productivity of Newaukum Creek. Photosynthetic organisms provide energy and autochthonous (i.e., produced instream) organic matter for consumption at higher trophic levels. Levels of aquatic primary production are primarily regulated by the availability of light, nutrients, water temperature, streamflow (and its connection to bed mobility), and grazing by aquatic herbivores (e.g., macroinvertebrates) (Murphy 1998). Three common forms exist; benthic algae, macrophytes, and phytoplankton, though the first two forms dominate in Newaukum Creek. We list several of the common representatives in each form to illustrate the variety of aquatic primary producers in the system. Comprehensive surveys of existing taxa in Newaukum Creek are unavailable, so we emphasize that only partial lists are provided here.

Benthic algae attaches to the streambed and underwater debris, and consists of diatoms (which form microscopic coatings on rocks) and macroalgae (in filaments, sheets or mats)(Murphy 1998). Algae is integrated with a complex mix of bacteria, fungi, inorganic sediments, and organic matter, collectively referred to as 'periphyton' (Murphy 1998). Diatoms are common during winter and in the shaded, high-gradient tributaries of the Upper Basin. They provide much of the high-quality forage for grazing macroinvertebrates, due to their relatively high energy content and vulnerability to grazing (see Murphy 1998). Taxa include *Cybella* and *Synedra* (Goldstein 1982), but probably also *Navicula* and *Meridion*. Desmids such as *Closterium* (spindle-shaped) and *Cosmarium* (ellipse-shaped) are common (Goldstein 1982). The dominant macroalgae is the filamentous green algae *Ulothrix* spp., particularly during summer in low-gradient stream reaches with high nutrient concentrations (e.g., the Plateau; Goldstein 1982). This filamentous algae is important because it forms the basic structure of algal mats in which diatoms are embedded. These diatoms are the primary food resource for aquatic herbivores (e.g., macroinvertebrate scrapers [e.g., *Dicosmoecus*], grazing snails [e.g., *Juga silicula*], and larval tailed frogs *Ascaphus truei* [see Section 9.1]), though filamentous algae is also somewhat vulnerable to grazing invertebrates (Murphy 1998).

Benthic algae is often inconspicuous, but its ecological importance should not be underestimated; the casual observer only sees what has not been eaten. Algae is replaced

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[45] Samples are replicated within basins but generally not at individual sites. Results are suitable for cross-basin comparisons and for evaluating trends over time, but have limited value for comparing the condition of sites within the Newaukum Creek Basin.

[46] Surveys conducted for King County Roads by ABR, Inc., on September 16, 2004. Data available from R. Fritz.

much more quickly than detrital inputs from riparian forests. Though the existing amount (i.e., standing crop) of leaves and twigs may greatly outweigh algal biomass at any given time, algae is constantly being renewed and therefore may be much more important in supporting biological production than appearances would suggest (see Hershey and Lamberti 1998).

Aquatic macrophytes include vascular angiosperms (flowering plants) that send roots into the streambed, and aquatic bryophytes that lack a vascular system (e.g., mosses and liverworts) (Murphy 1998). Vascular plants either live submerged underwater or float on the surface, and either root in the streambed or dangle their roots in the water column. Floating plants can be either attached or unattached, whereas submerged plants are usually rooted in place. Mosses can function as excellent invertebrate habitat by trapping food particles and provide refuge from streamflows for a variety of genera (Suren and Winterbourn 1992).While living, these plants are generally not important food resources for aquatic herbivores, but may be important after they die and enter the detritivorous food chain or create cover from predators for juvenile fish. They may also play an important role in nutrient cycling within the basin.

Phytoplankton likely occurs in Newaukum Creek, though much of it probably originates from standing (i.e., lentic) water bodies such as wetlands and ponds that are connected to the river network. True phytoplankton is uncommon in small streams, where the residence time of the water is insufficient for the development of sizeable phytoplankton populations. Most suspended algae are instead benthic algae or diatoms that have been sheared off the streambed (Murphy 1998).

Primary production supports a variety of grazing and scraping aquatic invertebrates (i.e., those feeding primarily on epilithic biofilms and periphyton) (Table 9). Recent surveys estimate that scrapers and grazers compose roughly 39.4 % (± 4.8 SD) of the aquatic invertebrate community in Newaukum Creek (Mc Elligott et al. 2005)[47]. Herbivore-piercers (which feed on macrophytes) are absent. Aquatic invertebrates have been sampled in numerous locations (Fig. 41) , including where the North Fork intersects 292nd SE and where the mainstem crosses the Veazie-Cumberland Road[48] (R. Fritz, *unpublished data*). Relatively few scrapers occur at these sites, including *Cinygmula* mayflies (Order Ephemeroptera, Family Heptageniiedae), and *Glossosoma* caddisflies (Order Trichoptera, Family Glossosomatidae). Aquatic wheel-snails (Family Planorbidae) are also present in Newaukum Creek and graze on biofilms (McElligott et al. 2005).

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[47] This figure excludes taxa that are present, but not assigned functional feeding groups.

[48] Surveys conducted for King County Roads by ABR, Inc., on September 16, 2004. Data available from R. Fritz.

Table 8. Benthic macroinvertebrate families (arthropods only) known to exist in Newaukum Creek (from McElligott et al. 2005; see that report for final identifications). Relative abundance (Rel. Ab.) is given as percent of the total number of individuals collected, for orders and for families. Other invertebrates, including mollusks, nematodes, platyhelminthes, and sponges are also present.

Order	Rel. Ab. (%)	Family	Genera	Rel. Ab. (%)	Frequency	Sampling location NEW 1667	NEW 2076	NEW 2102	NEW 2128	NEW 2151
Coleoptera	10.8%	Dytiscidae	-	0.2%	1 of 5			5		
		Elmidae	4	10.6%	5 of 5	86	62	74	6	15
Diptera	36.0%	Blephariceridae	1	0.2%	3 of 5			1	2	1
		Chironomidae	-	27.4%	5 of 5	98	114	178	150	87
		Empididae	-	0.5%	4 of 5	1	6	2	3	
		Pelocorhynchidae	-	0.2%	2 of 5			2	2	
		Psychodidae	2	5.2%	5 of 5	2	20	28	46	23
		Simuliidae	1	0.9%	5 of 5	3	2	1	6	8
		Tipulidae	6	1.6%	3 of 5	20	1			16
Ephemeroptera	24.0%	Baetidae	2	10.8%	5 of 5	126	29	30	10	51
		Ephemerellidae	4	6.2%	5 of 5	1	5	91	14	30
		Heptageniidae	5	5.6%	5 of 5	3	64	11	23	27
		Leptophlebiidae	1	1.5%	5 of 5	2	4	5	10	13
Plecoptera	18.6%	Chloroperlidae	2	9.4%	5 of 5	2	89	24	52	47
		Leuctridae	1	0.3%	2 of 5				1	5
		Nemouridae	2	6.7%	5 of 5	4	12	36	81	20
		Perlidae	1	0.8%	4 of 5		3	3	1	11
		Perlodidae	2	1.5%	4 of 5		13	7	11	3
Trichoptera	10.5%	Brachycentridae	1	0.1%	2 of 5	2				
		Glossosomatidae	2	6.6%	5 of 5	45	13	43	27	24
		Hydropsychidae	1	0.0%	1 of 5		1			
		Lepidostomatidae	1	1.0%	1 of 5					23
		Limnephilidae	1	0.2%	1 of 5					4
		Philopotamidae	1	0.2%	1 of 5		4			
		Rhyacophilidae	1	2.3%	4 of 5	16	12	3		21
		Uenoidae	1	0.1%	1 of 5		3			

The long history of riparian forest clearing, agriculture, livestock grazing, and urban development within the Newaukum Creek basin has likely altered levels of aquatic primary productivity. No site-specific studies have been conducted, though substantial evidence exists from observations in other systems (see review by Murphy 1998). For example, forest clearing along relative small streams such as Newaukum Creek consistently results in temporary enhancement of primary production (Lowe et al. 1986, Murphy 1998). Increased production funnels more energy into the aquatic food web, supporting higher levels of production in both fish and aquatic invertebrates (Murphy and Meehan 1991, Bilby and Bisson 1992). Increasing the biomass of benthic algae leads to higher productivity in invertebrate communities directly – by improving food quality (Behmer and Hawkins 1986) - and indirectly, as the community is increasingly dominated by species with rapid life cycles (Gregory et al. 1987). Specifically, Newaukum Creek is likely dominated by grazing invertebrates in areas where riparian forests have been cleared, and gravel or cobble substrates persist.

The long-lived Western pearl shell mussell

One interesting and potentially important filter feeder that exists in Newaukum Creek (B. Brenner, *pers. comm*.) is the Western pearl shell mussel (*Margaritifera falcata*). This mussel is relatively unique among other detritivores in the system in that it is extremely long-lived. The average lifespan of a Western pearl shell mussel is 60-70 y, and some live >100 years. They are much more long-lived than fingernail clams (Family Pisidiidae), which typically live less than four years (Holopainen and Hanski 1986). Maturation is also delayed until they reach 9-12 years in age. Their ecology is intimately linked to stream fishes, which host their larvae and assist in their dispersal throughout the channel network, including: *O. clarki clarki, O. mykiss, O. tshawytscha, O. kisutch, O. nerka, Rhinicthys osculus*a (see later sections for details on these fishes). Fertilization occurs in early spring; males release sperm and females 'inhale' them from the water column. Females are gravid from May to July. They then release glochidia (larvae) which attach to fish gills, where they remain for days to months. After they leave the host fish, the larvae burrow into stream sediments, where they remain for a few years to indefinitely. Preferred habitats for these mussels are cold, clean streams and rivers supporting salmonids. In particular, they dwell in stable sand, gravel, cobble substrates near the leeward side of large boulders or along banks. Aggregations can reach very high densities (e.g., hundreds of mussels per m^2). Restoration activities that benefit salmonid fishes are generally expected to aid Western pearl shell mussels, as well, given the similarity in their habitat requirements and their commensalistic relationship (i.e., one animal benefits and the other is not harmed). Special consideration is warranted to their vulnerability to rapid deposition of fine sediments.

Higher prey availability – due to increased algal biomass - can lead to strong and predictable shifts in the density of some species of juvenile fish (e.g., *Oncorhynchus kistuch*; Murphy et al. 1981) which respond by adjusting (decreasing) the size of their feeding territories (Dill et al. 1981). Nutrient enrichment, like forest clearing, can produce similar increases in the growth and abundance of benthic algae and associated invertebrates and fish at higher levels in the food web (see Hershey et al. 1988, Johnston et al. 1990). However, in systems where fish populations are limited more by spawning or refuge habitat (food is not limiting), enhanced aquatic primary production may be of little consequence (e.g., Murphy et al. 1986).

Thus, it is vital for restoration efforts to recognize that aquatic primary production varies throughout a stream, across seasons and years, and is not necessarily positively correlated with the biological integrity of a stream ecosystem (Karr and Dudley 1981). Equal or greater attention must be focused on ensuring proper system function and the availability of diverse sources of energy for aquatic communities (Murphy 1998).

9.2.2. Aquatic Detritus and Detritivores

Aquatic detritus and the detritivores that consume it (e.g., aquatic macroinvertebrates [collector-gatherers, filter feeders and shredders], crayfish, mussels, and some fish) play an important role in supporting the productivity of the instream communities in Newaukum Creek. Detritivorous organisms capture and consume dead plant and animal matter (e.g., microbes, leaves, twigs, carcasses) that would otherwise be transported downstream. In contrast to primary producers, these materials often originate from riparian forests bordering the stream, which is thus termed 'allochthonous' organic matter. The material entering Newaukum Creek varies greatly in size, quality (e.g., energy and nutrient content); each of which likely varies along the length of the stream, depending on the composition of the riparian forest. These differences are likely reflected in the composition of the detritivorous animal community inhabiting the streambed.

Coarse particulate organic matter (CPOM; organic particles > 1 mm) and the microbes that colonize it (e.g., algae, bacteria, fungi, protozoans) represent a major food source for 'shredding' invertebrates. Recent surveys estimate that shredders compose roughly 16.3 % (± 4.5 SD) of the aquatic invertebrate community in Newaukum Creek (Mc Elligott et al. 2005) (Table 9). CPOM consists primarily of leaves entering streams during fall, but also includes agricultural detritus, dead aquatic macrophytes, and particles from decaying salmon carcasses. Shredding invertebrates process much of this material into smaller particles that can be more fully utilized by other members of the biotic community. Stream surveys indicate that and *Lepidostoma* caddisflies (Order Trichoptera, Family Lepidostomatidae) are important shredders in the North Fork and mainstem of Newaukum Creek (R. Fritz, *unpublished data*). These have been found in locations along the Plateau. Prior studies suggest that bits of flesh from decaying salmon carcasses may also represent an important food resource for some stream fish (see Bilby et al. 1999). Communities relying on CPOM likely dominate in the upper basin, and to a lesser extent, in the ravine.

Fine particulate organic matter (FPOM; between <1 mm and 0.45 µm) is both generated and consumed by filter-feeding invertebrates, freshwater clams and mussels, and larval Pacific lamprey (ammocoetes). FPOM originates from a variety of mechanisms, but primarily consists of feces, processed leaf particles, microbes and their byproducts, and clumps of DOM that have stuck together (flocculated) (Hershey and Lamberti 1998). This resource is rough 10 times as abundant as CPOM (Wallace and Grubaugh 1996), providing energy and nutrients to collector gatherers, including *Baetis* (Order Ephemeroptera, Family Baetidae) and *Attenella* mayflies (Family Ephemerellidae), and *Heterlimnius* beetle larvae (Order Coleoptera, Family Elmidae). Recent surveys estimate that the majority (48.6 %, ± 8.4 SD) of the aquatic invertebrates in Newaukum Creek are collector-gathers, (Mc Elligott et al. 2005) (Table 9). Filtering collectors also exist in Newaukum Creek, including net-spinning *Hydropsyche* caddisflies (Order Trichoptera, Family Hydropsychidae) and Chironomids (Order Diptera, Family Chironomidae) (R. Fritz, *unpublished data*). Collector-filterers compose 11.5% (± 8.4 SD) of the macroinvertebrate community. Oligochaetes (worms) and fingernail clams (Family Pisidiidae) also occur in Newaukum Creek, and these organisms play important roles as collector gatherers. Stream communities relying on FPOM likely dominate across the Plateau. Dissolved organic matter (DOM) is not a major food source for stream organisms, except for microbial communities and perhaps larval black flies (Hershey and Lamberti 1998).

Newaukum Creek – particularly Big Spring Creek, the North Fork of Newaukum Creek, and Stonequarry Creek (R. Fritz, *pers. comm.*) - is also home to detritivorous fish – specifically, lamprey (Family Petromyzontidae) larvae called 'ammocoetes'. Adult lampreys construct nests in gravel-bed streams by using their mouths to move stones into position. Eggs hatch into ammocoetes, which lack developed eyes and do not possess the sucking discs that typify adults. Ammocoetes remain buried in stream substrates, feeding on FPOM strained from the water column for roughly four to five years before metamorphosing (Eddy and Underhill 1978). Lamprey are commonly observed in the basin (T. Fields, MSFEG, *pers. comm*.). One lamprey (80 mm) was observed in the lower Ravine by snorkelers (TetraTech, 2005, *unpublished data*). Lampreys (i.e., roughly 10 per season) are regularly observed during spring in smolt traps in Big Spring Creek (Mid-Sound Fisheries Enhancement Group). The taxonomy of fish in these sightings was not confirmed, though most were likely the detritus-eating Western brook lamprey *Entosphenus tridentatus*. This species eats detritus, and remains in fresh water for the duration of its life (Wydoski and Whitney 1996). Pacific lamprey *Lampetra pacifica* may also be present, but was not be confirmed. In contrast to the brook lamprey, Pacific lamprey forage on the bodily fluids of other fishes while at sea (e.g., predaceous or parasitic relationship). The adult Pacific lamprey is anadromous, returning to freshwater streams to spawn.

9.2.3. Aquatic Predators

Macroinvertebrate predators compose roughly 33% of the aquatic invertebrate community in Newaukum Creek; 26.4 % (± 8.9) are predator-engulfers and 6.9 (± 4.1) are predator-piercers (McElligott et al. 2005). Specifically, the free-living caddisfly *Rhyacophila* (Order Trichoptera, Family Rhyacophilidae) is an important aquatic predator occurring in the North Fork and mainstem of Newaukum Creek (R. Fritz, *unpublished data*). The predatory stonefly *Sweltsa* (Order Plecoptera, Family Chloroperlidae) is also present at these locations.

The primary amphibian predator in Newaukum Creek and its tributaries is likely the larvae of the Pacific Giant salamander *Dicamptodon tenebrosus*. Larval Pacific Giant salamanders likely inhabit the steep, cold, shaded tributary streams of the upper Newaukum Creek basin, including the North Fork and mainstem. This species is adapted to stream life; larvae have short, bushy gills and a long, powerful dorsal tail fin that makes it a strong swimmer (see Leonard et al. 1993 for life history details that follow). Females appear to breed year round, laying < 100 large eggs at a time. Each egg is attached to a rock or log, and guarded throughout development. Larvae remain instream for at least two summers; during this time they act as formidable predators. After this period of development, larvae may metamorphose into large adults – capable of eating small reptiles and rodents. However, some larvae remain instream and achieve sexual maturation while retaining a larval body form (this is termed neoteny). Stream sampling by King County Roads verified the presence of Pacific Giant salamander larvae in the lower reaches of Big Spring Creek in September 2006 (R. Fritz, KC *unpublished data*). Northwestern salamanders *Ambystoma gracile* – a pond-adapted species – are also commonly observed in Big Spring Creek (Mid-Sound Fisheries Enhancement Group).

At least four bird species are fish-eating (piscivorous), and thereby qualify as important aquatic predators. Three of these – Osprey, Great Blue Heron, and Bald Eagles – are described in Section 9.1. The Belted Kingfisher *Ceryle alcyon* is a conspicuous fish predator along Newaukum Creek. Common mergansers *Mergus merganser* also commonly prey on stream fishes in the Green River, though may not occur in Newaukum Creek.

River otters *Lutra canadensis* may have once been important aquatic predators in Newaukum Creek, but this species is not known to occur there now. In contrast, muskrats *Ondrata zibethica* occur in isolated locations. Muskrat feed on fish, mussels, and amphibians. They construct houses in shallow water or dig burrows in streambanks (though these are rarely evident because entrances are underwater). These animals breed multiple times per year from late spring through summer.

The majority of fish species in the Newaukum basin prey upon aquatic invertebrates, riparian arthropods, or other fish. We organize following subsections around the basic life cycle of stream fish (Table 8), as envisioned by Schlosser (1991). Our rationale is that it is vital to match the description of fish habitat to the intermediate scales in which stream fish carry out critical life-history events and the scales at which natural resource managers can affect change (Fausch et al. 2002).

Table 9. Factors considered in characterizing stream fish species

Factor	Details
Stock origin	Wild or hatchery-origin and stock status based on assessments by Washington Department of Fish and Wildlife
Life history and genetic variation in the population	This includes life history traits (phenotypes) present or expressed. This is valuable information – where available – because genetic variation is the 'unseen basis' for the biological outcome of restoration (Falk et al. (2006).
Spawning habitat	Characteristics and distribution of spawning habitat, including redd site selection and construction, and egg incubation to emergence.
Feeding habitat	Distribution and characteristics of feeding (rearing) habitat; areas with seasonally favorable growth conditions, including plentiful food and energetically profitable stream hydraulics and water temperatures.
Refuge habitat	Refugia (i.e., for overwintering or oversummering) habitats. These areas may have seasonally unfavorable growth conditions, but provide refugia for fish during harsh winter floods, or intermittent flows during late summer.
Habitat connectivity	Connectivity among habitats is vital for spawning migrations, feeding migrations (from spawning habitats to feeding habitats, and overwintering habitats to feeding habitats) and overwintering migrations (from feeding habitats to refugia). Connectivity is also important to sustain metapopulation dynamics; at larger scales, isolated populations are not likely to survive indefinitely.

Chinook salmon - *Oncorhynchus tshawytscha*

See Section 9.1.

Coho salmon - *Oncorhynchus kisutch*

Coho are thought to have historically been the dominant Pacific salmonid in Newaukum Creek (Boehm 1999). Coho in Newaukum are part of the Green River/Soos Creek stock (# 3140), which is considered to be mixed with composite production. The stock was declared healthy in both 1992 and 2002 by the Washington Department of Fish and Wildlife. Hatchery coho salmon were introduced into Newaukum Creek from Soos Creek, Puyallup, and Issaquah facilities[49]. Genetic analysis indicates Soos Creek hatchery coho salmon exhibit strong genetic differentiation from all other Washington coho stocks (of those examined).

Coho salmon spawning habitat is distributed throughout much of the channel network comprising Newaukum Creek. Adult coho salmon generally return to spawn after one full year at sea. Numbers of spawning adults vary among locations and among years (Fig. 40). Prime spawning areas are located in Big Spring Creek, in the mainstem across the upper Plateau (RM 10-12; RK 16.1-19.3), and in the North Fork (see Goldstein 1982, p. 23).

Coho salmon rely on high quality freshwater feeding (rearing) habitat due to their long stream residence. Fry emerge from redds at approximately 30 mm long and migrate to sea in the spring after their first or second year of stream residence, spending little or no time in estuaries (Quinn 2005). The Newaukum Creek basin offers feeding (rearing) habitat throughout remaining natural

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[49] Releases occurred (at least) in 1978, 1977, and 1980, ranging from 37,000 to 245,000 individuals (see Goldstein 1982).

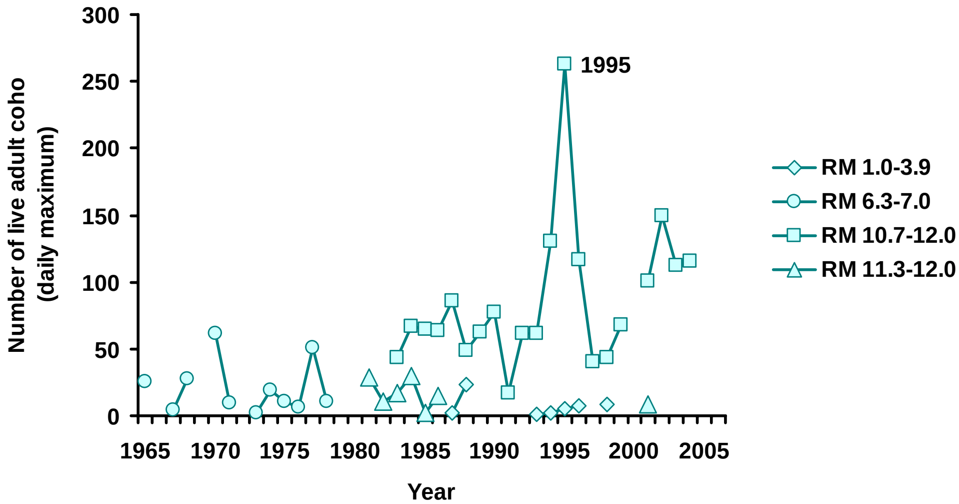
watercourses and some drainage ditches. The best rearing habitat likely exists in Big Spring Creek, the North and South Forks of the mainstem; though the road culvert along the North Fork at 292nd may - at times – potentially block juvenile fish passage (R. Fritz, *pers. comm.).* On average, roughly 1,400 coho smolts (ranging from 569 to 2006 fish between 2003 and 2006) outmigrate from Big Spring Creek, typically from mid-April to early May[50]. Outmigrating smolt typically range from 100 mm to 125 mm in size. Coho ranging from 55-100 mm in length were observed in Big Spring Creek during September 2006 (R. Fritz, KC *unpublished data*). Summer rearing habitat also exists in Watercress Creek, from the confluence with the mainstem to the 442nd Street intersection, in Stonequarry Creek along Veazie-Cumberland Road (though low flows and poor water quality in late summer can be problematic) and in an drainage ditch downstream connected to the mainstem at RM 6.8 (R. Fritz, *pers. comm.*). Coho juveniles also rear in the Ravine; recent surveys estimated juvenile coho abundance in the lower Ravine ranges from 0.034 to 0.072 fish m^{-2} among reaches, in mid-June (TetraTech, 2005, *unpublished data*). In 2006, coho represented 27-44% of the total fish abundance (among reaches), ranging from 10 to 130 mm in total length. Most (i.e., 50-74% among reaches) occurred in slow water habitats or in association with large wood (i.e., 13-41%).

Refuge habitats for overwintering and over-summering juvenile coho are relatively scarce due to the pervasive lack of complex habitat (e.g., instream wood, side channels with abundant cover) and pools. Exceptions can be found in portions of the mainstem in the ravine (e.g., upstream from the Whitney Bridge), side channel complexes in Mahler Park and Big Spring Creek, and numerous restoration projects involving wood supplementation (e.g. Malatesta site at RM 12, dam removal site on North Fork). Ditches may also offer some refuge from winter floods, similar to refugia provided by wall-base channels, though this has not been evaluated. Investigations of potential passage barriers to adult and juvenile migrants are ongoing.

Optimal temperatures for coho salmon vary among life stages (see review by Richter and Kolmes 2005). Spawning migrations tend to occur when temperatures are below 15.6˚C. Incubation temperatures of 2.5-6.5˚C are optimal for eggs, compared to 4-8˚C for alevins, though survival and health appears acceptable below 11-12˚C. Juveniles grow fastest in average water temperatures of 12-15˚C; the 7-DAM should not exceed 14-17˚C**.**

[50] Mid-Sound Fisheries Enhancement Group has studied coho salmon migration in Big Spring Creek since 2003 using a smolt trap: http://www.midsoundfisheries.org/SmoltTrap%20Data%20Overview.htm. Variation in smolt outmigration timing: http://www.midsoundfisheries.org/Spring%202006.pdf. Juvenile coho salmon constitute 65-92% of the fish caught in the smolt trap.

Figure 40. Historical counts of adult (spawning) coho salmon at four different index reaches of Newaukum Creek. Values depict the maximum number of live adults observed in that year (usually among six to ten dates of observation during spawning season). Note that observations were missing in many years. These observations are presented to illustrate trends across time at individual reaches, but should not be used for cross-reach comparisons.



Chum salmon - *Oncorhynchus keta*

Newaukum Creek contains Crisp Creek fall chum (stock # 2154); one of the two stocks of chum salmon in the Duwamish/Green River basin. This is a non-native stock with composite production supported by the Keta Creek Hatchery (operated by Muckleshoot Tribe). This stock is genetically indistinguishable from Quilcene hatchery chum (Phelps et al. 1995), which was the founding broodstock (also some from Hoodsport). Efforts are underway to replace this stock with one from another south Puget Sound system (Suquamish Tribal Hatchery; WDFW 2002). The historical abundance and distribution, nor present status is well known. Life history variation in fall chum salmon within Newaukum Creek has not been described.

Newaukum Creek offers spawning habitat for chum salmon, which generally return to spawn after 3-5 years at sea, where they attain large sizes (e.g., 3-5 kg; Quinn 2005). Spawning occurs from late November through December (WDFW 2002), primarily within the first mile of the North Fork of Newaukum, the first 0.6 mile of Big Spring Creek, and in the South Fork of the mainstem. Reaches located in RM 4.6-10 are also thought to comprise important spawning habitat (see Goldstein 1982, p. 23). Chum salmon eggs are relatively large, producing fry that measure 32-38 mm in length upon emergence.

Feeding (rearing) habitat within Newaukum Creek is relatively unimportant for juvenile chum salmon. Juveniles have small parr marks for camouflage, however most depart to downstream estuaries immediately after emerging from the gravel, or remain in their natal stream for only a few days or weeks. The lower 1.6 km of the South Fork Newaukum Creek is considered rearing habitat (WDFW SalmonScape). Due to their brief stream residence, the availability of overwintering and oversummering habitats in Newaukum Creek is likely unimportant for juvenile chum salmon production.

Passage barriers likely do not limit chum salmon adults from access to spawning habitat, nor does it limit juveniles migrating downstream.

Pink salmon - *Oncorhynchus gorbuscha*

The status of pink salmon in Newaukum Creek is unknown and potential life-history variation in juvenile pink salmon has not been examined. Spawners return in odd years (e.g., 2005, 2007) to spawn in lower reaches of rivers. Adult pink salmon spawn in Newaukum Creek up to RM 8 (RK 12.9), though most spawning occurs in the first mile (1.6 km) upstream from the confluence with the Green River. Pink salmon are characterized by high spawner densities, small eggs, and slim-bodied silver fry measure 29-33 mm long when they emerge from the gravel (Quinn 2005). Fry migrate directly to the ocean, meaning freshwater habitats for rearing and overwintering are unimportant for pink salmon production.

Coastal cutthroat trout - *O. clarki clarki* (resident and migratory forms)

Native coastal cutthroat trout are likely the most abundant, widely distributed salmonid in Newaukum Creek (Fig. 42)[51]. The stock (# 7830) status is unknown. Green River cutthroat trout are genetically distinct from other populations in south Puget Sound, based on allozyme (protein) markers (33 loci) and microsatellite analysis (6 loci) (WDFW). Coastal cutthroat trout exhibit substantial life history variation (see review by Trotter 1989). Both migratory and nonmigratory life history forms are thought to be present (WDFW 2002; Boehm 1999).

Newaukum Creek provides habitat for spring-spawning coastal cutthroat trout, though spawning and migration timing is unknown. River-migrating individuals may enter natal streams from July through October and spawn from January to May (WDFW 2002)[52]. Other life history forms likely spawn from January through mid-June (WDFW). Coastal cutthroat are iteroparous (repeat spawners), spawning up to two or three times in their lifetime (Trotter 1989). Spawning occurs in riffles with pea-gravel substrates under 15-45 cm of water (Trotter 1989); often in pool tail-outs.

Feeding (rearing) habitat exists throughout Newaukum Creek, including Big Spring Creek. Newly-emerged fry measure 25 mm and dwell in low-velocity habitats along channel margins, in backwaters, and in side channels (Trotter 1989). Amphidromous individuals typically outmigrate to river mouths and estuaries after 3-5 years in freshwater, ranging from 20-25 cm in length (Fuss 1982). Fluvial (or potomodromous) individuals use mainstem rivers (e.g., Green River) as feeding habitats. In contrast, nonmigratory individuals migrate little, mature early, and die young (e.g., within three or four years; Trotter 1989). Oversummering juveniles feed on drifting invertebrates from lateral habitats and move to pools with the onset of fall. Recent surveys (late July 2006) estimated cutthroat trout represented 1 to 3 % of the total fish abundance (among

[51] We predicted the probability of trout presence in the upper basin (Fig. 42) from stream gradient using model A_G from Latterell et al. (2003). This model predicts the trout presence in 100 m stream reaches with 72% accuracy (where presence was assumed at probabilities ≥0.50), assuming no downstream passage barriers exist. Predictions are solely based on the stream gradient of the 100 m reach downstream from each point (Fig. 43). This model does not predict the upstream limit of trout distribution *per se*. Instead, it is intended to be an empirically-based, probabilistic decision-making tool for determining which roads cross stream reaches that are likely to contain fish, and for estimating the likelihood and extent of fish presence upstream from individual crossings. It is up to the user to decide whether the results sufficiently justify the repair of perched culverts on a site-by-site basis. Note that GIS-derived stream gradient typically underestimates true gradient because small channels are almost always more sinuous than depicted on stream maps (Latterell et al. 2003).

[52] This assumes similarities with coastal cutthroat trout in the Snohomish River.

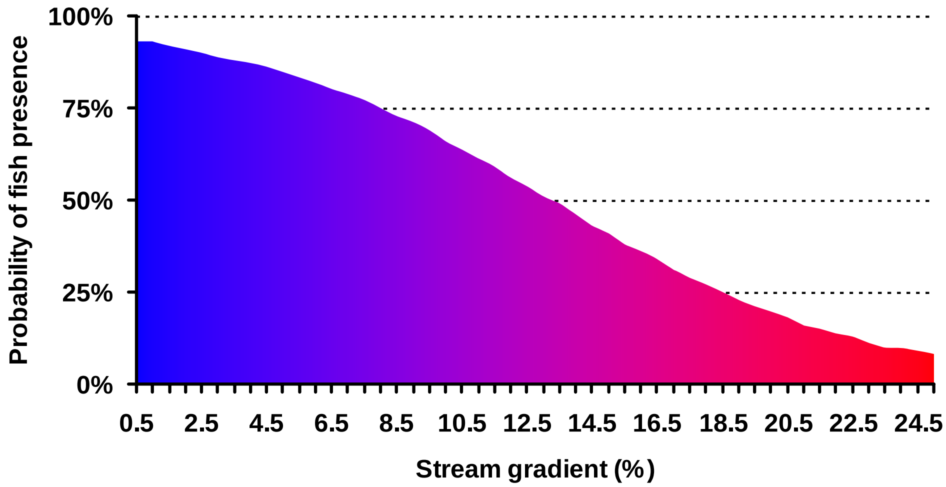
reaches), ranging from 30 to 260 mm in total length (TetraTech, Inc. 2005, *unpublished data*). Cutthroat inhabited both fast and slow-water units within the stream.

Perched culverts at road crossings represent a potential threat to connectivity between stream habitats for coastal cutthroat trout in Newaukum Creek – particularly if and where they exist in low-gradient reaches in the Plateau. A comprehensive survey for potential fish migration barriers has not been conducted. However, we observed that 10 of 14 channels (mean wetted width 1.3, ± 0.8 SD) intersected by the old Weyerhaeuser mainline road had culverts that were 'perched' by > 30 cm and 7 of 14 were perched by over 0.5 m (up to roughly 2 m). However, our analysis (Fig. 42) suggests there is little chance that trout would be present either immediately downstream or anywhere upstream from the point where streams intersect the mainline road.

Figure 41. Map of Index of Biotic Integrity scores at sampling stations.
PLEASE SEE SEPARATE FILE

Figure 42. Map of probability of fish presence in streams of the Upper Basin.
PLEASE SEE SEPARATE FILE

Figure 43. Modeled probability of fish (trout) presence in individual 100-m stream reaches where fish passage is not blocked downstream. Values represent results from model A_G in Latterell et al. (2003).



Threespine stickleback - *Gasterosteus aculeatus* Linnaeus

Newaukum Creek provides habitat for threespine sticklebacks, known to inhabit the lower reaches of Big Spring Creek, Stonequarry Creek, and the ditch joining the mainstem near RM 6.8 (R. Fritz, *pers. comm*, King County *unpublished data*, Mid-Sound Fisheries Enhancement Group[53]). This species lives in both freshwater and the marine environment, foraging on zooplankton, snails, and insects (Wydoski and Whitney 2003). In Washington, the freshwater residents spawn from May-July, and the marine form migrate up rivers in early June to spawn. Spawning habitats vary strongly from salmonids, in that stickleback do not construct redds. Instead, they build elaborate nests by building a nest from algae and detritus cemented together with gluey kidney secretions; these nests are spheres about 5 cm in diameter (Wydoski and Whitney 2003). Fertilized eggs (100-150 from freshwater form, compared to 250-300 from marine form; Wydoski and Whitney 2003) are protected in the nest and defended by the male until hatching a week later. Most adults die after spawning.

Sculpin - *Cottus spp.*

Newaukum Creek provides habitat to native sculpin, which have been observed in Big Spring Creek, Stonequarry Creek, the mainstem and North Fork (R. Fritz, *pers. comm*, King County *unpublished data*, Mid-Sound Fisheries Enhancement Group[53]). This genus likely occurs in most of the channel network, as they are often pervasive. No site-specific information exists regarding the life history of this genus within Newaukum Creek, however see Wydoski and Whitney (2003) for details on individual species and their general distribution. Recent surveys estimated that sculpin represented 2% of the total fish abundance in reaches in the lower

[53] http://www.midsoundfisheries.org/SmoltTrap%20Data%20Overview.htm

portion of the Ravine (TetraTech, Inc. 2006). Individuals ranged from 30 to 75 mm in total length. Most were found in fast water units.

Speckled dace - *Rhinicthys osculus*

Newaukum Creek provides habitat to speckled dace, which are known to inhabit the North Fork (R. Fritz, *pers. comm.*). In general, speckled dace inhabit small, swift streams and prefer water temperatures ranging from 9-11˚ C. No site-specific information exists regarding the life history of this species within Newaukum Creek. However, recent surveys estimated that dace represented 0 to 2% of the total fish abundance, ranging from 25 to 120 mm in total length. Most were found in fast water units.

9.3. WETLAND COMMUNITIES

This section briefly identifies and describes the remaining wetland areas with the highest values to wildlife. We also identify some of the species that use these areas, including nonnative invasive plants. In general, the Westside Riparian-Wetlands habitat type comprises wetland patches or linear forested riparian zones occurring in areas with wetland hydrology or soils, periodic riverine flooding, and perennial flowing freshwater (Chappell et al. 2001). This wildlife habitat type includes both wetlands and riparian zones, and therefore both are sometimes discussed together in this section.

The wetlands remaining in Newaukum Creek basin that likely provide the highest amount of value for wildlife are those with native vegetation. A total of approximately 407 acres of wetlands are present in Newaukum Creek basin that are categorized as forested, scrub-shrub, emergent, or open water wetland types. These wetlands are scattered across the basin in largely unconnected fashion (in other words, most of them are not forming wetland complexes; Figure 24). Regardless of hydrology, the emergent zone of wetlands is the most important for breeding amphibians, and it is also the most biologically productive area of the wetland. Wetland complexes are especially important because amphibians and other wildlife may still find water and breeding and foraging habitat when one or more of the other wetlands of a complex dries and is unavailable for use.

Two wetland areas stand out as providing the most actual and potential wildlife function. The first of these two wetlands lies north of the City of Enumclaw, south of 424th, along the left bank of Newaukum Creek. Black cottonwoods and red alder are the dominant canopy species, and willow and red-osier dogwood are present in the midstory. A small tributary flows out of this forested wetland into a roadside ditch along 424th. This wetland represents one of the most valuable wildlife habitat areas on the Plateau because of its relative size, the native vegetation present, and because of the presence of forest, wetland, and riparian habitat all in one location.

The second wetland of high value to wildlife is the forested wetland complex upstream of Big Springs Creek, including Mahler Park. Both of these wetlands are remnants of what were once much more extensive, connected wetlands. Each of these areas contain invasive species, including Himalayan blackberry, reed canarygrass, English ivy, and English holly, yet they retain diverse plant communities in terms of species composition, structure, and age. Animals breeding in these small wetlands are more vulnerable to predation, diseases, and human disturbance than species in much larger wetlands with naturally vegetated buffers. Nonetheless, these two wetland complexes offer the best available habitat on the Plateau in the basin.

The remainder of wetlands in the Newaukum Creek basin is highly altered and has limited value to wildlife in their present state. For example, “wet fields” occupy approximately 70% of wetlands in this basin (Table 3). Where wet fields are farmed for crops, seeds and grains that remain on the ground may provide valuable food for migrating and over-wintering birds such as American wigeon *Anas americana*. However, many of these wet fields contain a mixture of invasive reed canarygrass, bentgrass, and bulrushes *Juncus effusus*, or the fields are surface-dry all or part of the year, and they are not connected to other wetlands. Such wetlands provide little food for waterfowl and, lack (a) breeding habitat for amphibians; (b) foraging habitat for shorebirds; (c) forested vegetation appealing to beavers and muskrats; (d) and permanent water or access for salmonids.

9.4. RIPARIAN PLANT COMMUNITIES

Riparian areas[54] are among the most ecologically important elements of the Newaukum Creek basin, because they regulate sunlight, and thereby influence stream temperatures and primary productivity (also called 'autochthonous' production) (see map of forest types in Fig. 44). Another reason riparian areas are important is because they deliver vital organic materials to streams, including leaves and large wood. As summarized in King County (2004):

Riparian areas provide a variety of functions including shade, temperature control, water purification, woody debris recruitment, channel, bank and beach erosion, sediment delivery, and terrestrial-based food supply (Gregory et al. 1991; Naiman 1998; Spence et al.1996). These [functions] are potentially affected when riparian development occurs (Waters 1995; Stewart et al. 2001; Lee et al. 2001). Bolton and Shellberg (2001) provide an extensive discussion of the effects of riparian and floodplain development on aquatic habitats and species. Effects include: (1) reduction in amount and complexity of habitat; (2) increased scouring of channels due to channel and floodplain confinement; (3) reduction or loss of channel migration, vegetation, sediment supply; and (4) woody debris recruitment.

Riparian areas are also major food sources for aquatic organisms. Specifically, they support the productivity of aquatic animals that consume plant and animal matter (also known as heterotrophic consumers), through delivery of energy resources (called allochthonous organic matter, when it originates from outside the stream). These resources include organic matter (such as leaves, twigs) supporting animals (many aquatic invertebrates) that feed on dead vegetation and carcasses (also known as detritivores) in the stream, as well as invertebrates (namely, riparian arthropods) that drop into the stream where they can be eaten by aquatic consumers such as fish (for example, juvenile coho salmon and cutthroat trout) and amphibians.

Riparian areas (and wetlands) are used disproportionately to their relative area by wildlife (Thomas et al. 1979; Gregory et al. 1991; Oakley et al. 1985; McGarigal and McComb 1992; Nilsson et al. 1989; Knopf 1985; Knopf et al. 1988). In Oregon and Washington, 82 percent of inland bird species use freshwater, riparian, and wetland habitats; 77% of species breed in riparian and wetland environments (Kauffman et al. 2001). Many groups of mammals rely on riparian zones, including bats, small mammals such as shrews, mice, and voles, and mammalian predators such as mink, river otters, and raccoons. Seventeen herptile species (reptiles and amphibians) are closely associated with riparian zones in the Westside Riparian/Wetland habitat type. An additional 13 species are either associated with or present in this habitat type in Washington and Oregon (Kauffman et al. 2001). Riparian areas are particularly important travel corridors for herptiles, due to their limited mobility and dispersal capabilities.

Wildlife use riparian areas for a variety of reasons. For example, in Washington, these areas typically have higher structural diversity and spatial heterogeneity than adjacent areas. They

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[54] Riparian zones are "transitional semiterrestrial areas regularly influenced by fresh water, normally extending from the edges of water bodies to the edges of upland communities" (p. 2, Naiman et al. 2005).

offer edge habitat (two or more habitats in close proximity), and reliable sources of water. Riparian areas produce substantial plant and insect biomass, which diminishes competition for food among consumers. Finally, riparian areas often provide more moderate microclimates than surrounding environments (Kauffman et al. 2001).

This section explains basic patterns in the native and current riparian forest community structure, composition and distribution including age, size, species composition, stand density and basal area, snag density. Between this and the next section, we contrast the typical pathways of vegetation succession in riparian and upland areas. Using generalized seral stages (steps in vegetation succession), we explain how the structure and composition of riparian forests change over time, including how they differ from one another. Specifically, we contrast the basic life history strategies of dominant plants and the primary mechanism used for reproduction, for each seral stage. We then explain the potential consequences of human alterations for forest regeneration, shade benefits to streams, delivery of wood, organic matter and insect prey to streams, and the development of productive riparian soils.

Boise Ridge in the Upper Basin is largely forested with conifer stands of various ages, reflecting a long (and continuing) history of timber harvest (Fig. 44). There is virtually no old growth forest remaining in this headwaters area and it appears that much of the area is in its third rotation of timber production. A network of logging roads, including many on steep sidehills, provides access for timber management and harvest activities.

Along the Plateau, the riparian vegetation has been more altered from its natural state than elsewhere in the basin (Fig. 44). Approximately 50 acres of riparian area (eight percent of total riparian area) is categorized as “agriculture or field” (Appendix D, Table D1), meaning that there is little to no discernable difference between the riparian vegetation and that of the surrounding field.

The riparian areas in the ravine are mostly forested and undeveloped (Table 10). Although the Ravine, like the rest of the basin, historically was logged of merchantable timber, the forest has been allowed to regenerate. The second-growth forest has been present long enough (80-100 years) to develop structural diversity in the canopy and understory. Generalized riparian conditions in the lower Ravine were recently (2006) evaluated by TetraTech, Inc. Surveys compared an ‘impact’ reach (i.e., site of future restoration project) and an upstream ‘control’ reach. The overstory density (above Newaukum Creek) was 76% (± 12 SD, among transects) in the control reach and 84% (± 12 SD, among transects) in the treatment reach. Deciduous vegetation dominated along roughly 91% of the control reach, and 77% of the treatment reach, whereas mixed conifer-deciduous overstory was relatively scarce.

Typically, wetland and riparian habitat would have either been shrubland (up to 30 feet in height) or forest (greater than 200 feet in height) or a mosaic of these (Chappell et al. 2001). Tree species were either conifer or hardwood or a mix. Some lowland forested wetlands may have been dominated by conifer trees. Large woody debris and snags would have been abundant in forested riparian areas and wetlands. The most dominant tree species was likely red alder, and other deciduous tree species would have included black cottonwood, bigleaf maple, and Oregon ash (Chapell et al. 2001). In the next sections, we identify the most obvious and important species in the riparian plant community, according to the successional stage in which it is most common.

9.4.1. Early-Seral Pioneers

Major riverine tree and shrub species can be generally classified into three groups according to their adaptation to disturbance –in this case, to floods (Naiman et al. 1998). ‘Invaders’ produce large quantities of seeds and branch fragments (known as propagules) that are dispersed by wind or water. These propagules colonize river sediments (also called alluvial substrates). In contrast, ‘endurers’ resprout from the stem or roots after being broken, partly buried by floods, or eaten by herbivores. ‘Resisters’ withstand flooding (or fires) during the growing season.

Table 10. Riparian landcover in Newaukum Creek basin.

Landcover type	Primary landcover class	
	“Stream/Riparian”	“Wetland”
forest	463	21
agriculture or field	38	11
shrub	38	23
ditch	11	2
recent clearcut	2	0
rural residential	1	<1
total	554	58

Pioneering species in riparian areas largely colonize surfaces created by floods; which distinguishes them from upland forest species that regenerate in fire-dominated areas. Riparian pioneers play a vital role in creating hydraulic roughness – slowing down flood flows, causing sediment deposition and alluvial soil formation (Latterell et al. 2006). These species also produce high-quality (nitrogen-rich) seasonal inputs of litter. Litter input supports the productivity of macroinvertebrate communities, especially those that consume detritus.

Pioneering trees and shrubs in riparian areas of Newaukum Creek are mostly deciduous species. Most riparian pioneers have flexible stems that resist breakage, or can sprout roots from buried bark along their trunk or from fragments snapped off during floods (known as adventitious roots). Willows *Salix spp.* have attributes that qualify them as invaders, endurers, and resisters (see above). Red alder *Alnus rubra* and black cottonwood *Populus trichocarpa* are classifed as invaders and as resisters. Riparian pioneers frequently regenerate from transported live fragments. For example, cottonwood trees can shed healthy branch tips into the stream. When these tips are deposited on river sediments, they sprout to form produce genetically identical trees (this process is referred to as ‘cladoptosis’).

Figure 44. Map of forest types.

PLEASE SEE SEPARATE FILE

9.4.2. Late-seral Canopy Dominants and Foundational Species

Late-seral canopy dominants are those trees that occupy most of the upper canopy at a late stage of forest stand development. Some of these species function as foundational species, which create substantial amounts of habitat for other species. For example, large conifer trees may host many other plant species either directly on their trunks or in their canopies, or indirectly create favorable microclimates for other species rooted beneath their canopies.

These are important species to consider during restoration planning. For example, it is vital to consider whether sources of seeds and propagules are nearby to sustain regeneration. Also, these are the species primarily responsible for the production and delivery of wood**,** because they are large and relatively durable instream. They also generate substantial shade, which helps to regulate water temperature. Finally, their massive canopies can have important influences on the hydrology of the basin because they affect soil moisture levels as they draw water from the ground, through their foliage, and into the atmosphere (evapotranspiration).

Late seral canopy dominants in riparian areas of Newaukum Creek include conifer trees such as: western redcedar *Thuja plicata*, western hemlock *Tsuga heterophylla*, Sitka spruce *Picea sitchensis*, and to a lesser extent Douglas-fir *Pseudotsuga menzeisii* (Chappell et al. 2001). Indeed, GLO surveyors in the late 1800s confirm the presence of "alder, Spruce, hemlock," as well as cottonwood and "fir" (Douglas-fir).

The existing canopy dominants in the Ravine include a mix of coniferous and deciduous species, including bigleaf maple *Acer macrophyllum*, black cottonwood *Populus trichocarpa* (early-seral), red alder (early-seral), Douglas-fir, western redcedar, and Sitka spruce. The conifer species and the cottonwood average 60 to 80 ft in height with diameters at breast height (DBHs) of about 18-20 inches; red alders average 40-50 ft in height with DBHs of 6-10 inches. These areas lack large snags: some may be present, but the area as a whole has not regenerated long enough to produce significant numbers of mature trees and snags.

9.4.3. Understory Trees and Shrubs

Understory trees and shrubs exist and regenerate under very different conditions than early-seral pioneer species. Dominant understory species in riparian areas under natural historic conditions included salmonberry *Rubus spectabilis*, salal, vine maple *Acer circinatum*, red-osier dogwood *Cornus stolonifera*, cascara, stink currant, devil's club *Oploplanax horridus*, thimbleberry *Rubus parviflorus*, snowberry *Symphoricarpos albus*, beaked hazelnut *Corylus cornuta*, and Pacific ninebark *Physocarpus capitatus* (Chappell et al. 2001). Under natural historic conditions, Pacific willow *Salix laciandra* and other willow species, including Sitka willow *Salix sitchensis* and Hooker willow *Salix hookeriana* would have comprised some shrub wetlands and riparian areas. Other species in these shrublands would have included Douglas spirea *Spiraea douglasii*, western crabapple *Malus fusca*, and sweet gale *Myrica gale* (Chappell et al. 2001). Some patches of Oregon ash communities may have been present in the Newaukum Creek basin. Patches of vine maple and Sitka alder may have occurred along streams of the Upper Basin.

In riparian zones that are vegetated as shrub or forest, the ground story appears to be predominantly Himalayan blackberry. Reed canarygrass is pervasive and may be present along streams in any of the landcover types. Although trees line the riparian zone in narrow bands in various places throughout the basin, at only two locations in the plateau does the forest extend beyond the riparian zone into a more extensive stand. One of these locations is the City of Enumclaw's Mahler Park, and the other is a forested wetland area just north of the city of Enumclaw on 424th. In both of these locations, Himalayan blackberry is one of the dominant groundstory shrubs. A variety of other shrubs are also present in the groundstory at Mahler Park, including salmonberry, snowberry, and another non-native species, English holly. Black cottonwood, Douglas-fir, red alder, and western redcedar comprise the canopy, and some of the cottonwoods are large enough that they may make sizeable snags in the not-too-distant future. English ivy is present on some of the canopy trees in this stand and could potentially cover all the large trees if not controlled. In the understory, some western redcedar saplings are growing.

9.4.4. Dominant Herbaceous Vegetation

Herbaceous vegetation is an important source of energy and nutrients for large herbivores, and contains substantial plant diversity. Dominant herbaceous species would have historically included slough sedge *Carex obnupta*, Sitka sedge *Carex aquilitis*, Dewey's sedge *Carex deweyana*, skunk cabbage *Lysichiton amercianum*, coltsfoot *Petasites palmatus*, Cooley's hedge-nettle *Stachys cooleyae*, stinging nettle *Urtica dioica*, and scouring rush *Equisetum telmetiea* (Chappell et al. 2001). Herbaceous plants of the Ravine include sword fern, reed canarygrass, and horsetail.

9.4.5. Non-native Vegetation

Invasive species are ubiquitous in the observed portions of riparian forests of Newaukum Creek. Reed canarygrass and Himalayan blackberry are most common and important, though English Ivy is also problematic in some locales.

Reed canarygrass is the most prevalent invasive species in the basin. It was introduced into the Pacific Northwest about 100 years ago. After an area was logged, reed canarygrass was planted because it helped break down stumps and log debris before crops were planted (USDA 2003). The species is problematic because it moves out of pasturelands and into stream bottoms and wetlands, and it may displace or prevent the establishment of native vegetation. It is also extremely difficult to eradicate once established. This monoculture reduces the amount of wildlife habitat for most native wildlife species by reducing: (1) habitat complexity, (2) a variety of forage plant species, and (3) the amount of other resources such as nesting materials. Conversely, it does provide shade and cover to aquatic areas and their invertebrates, fish, and amphibians. Reed canarygrass was present at nearly every Newaukum Creek road crossing that was viewed. Additionally, most of the "wet field" wetlands are covered in this aggressive species. Reed canarygrass may be also be found growing in the narrow floodplain of the creek near the confluence with the Green River (in the Ravine).

Himalayan blackberry is another prevalent non-native species in the Newaukum Creek basin. Himalayan blackberry was observed at every viewing location of the riparian zone within the Ravine to varying degrees. This shrub provides forage for birds such as Spotted Towhees and thrushes and omnivorous mammals, including coyotes, squirrels, and black bears. It also provides cover for birds and mammals. American Robins and Swainson's Thrushes may nest in these shrubs. However, Himalayan blackberry can form large impenetrable thickets, the density of which can reach 525 canes per square meter (Alaska Natural Heritage Program 2005). The thickets create dense shade, reduce native species diversity, and likely limit mammal movement (Alaska Natural Heritage Program 2005). In fact, Himalayan blackberry is allelopathic, which means that it releases a toxin into the soil that suppresses the growth of other plants such that understory competition is weakened and killed. Himalayan blackberry was noted in most small forest patches on the Plateau, in riparian areas of the Ravine, and at most of the road crossings of Newaukum Creek.

9.5. UPLAND FOREST PLANT COMMUNITIES

Upland forest was historically (and currently remains) the most extensive habitat type in the lowlands of Western Washington (Chappell et al. 2001). In the Newaukum Creek basin, it formed a matrix with other habitat types (Table 11). "The forests of western Washington…are the archetype of mesic temperate forests in the world….The environment is mild and extremely favorable for forest development" (Franklin and Dyrness 1973, pg 44).

Currently, the Newaukum Creek basin contains roughly 5,202 acres of upland forest (Table 11; Appendix D, Table D1)[55] (Fig. 44). Although the age and composition, not to mention the sizes, of these forest patches vary considerably, there are three general types of forest stands present in the basin: (1) deciduous; (2) conifer; and (3) mixed (Table 11). These stands range in size from very small patches under one acre to large connected forest in the Upper Basin (Forest Production District).

Table 11. Area of upland forest types inside and outside the Forest Production district in the Newaukum Creek basin based on 2005 aerial imagery and field reconnaissance.

Forest Type	Inside FPD (acres)	Outside FPD (acres)	Total (acres)
Conifer	2,756	478	3,234
Hardwood	31	244	275
Mixed	34	1,608	1,642
Recent Clearcut	51	0	51
Total	2,872	2,330	5,202

Conifer stands are almost exclusively composed of Douglas-fir in the Upper Basin, within the Forest Production District (FPD), because existing forest is being managed as high-yield Douglas-fir monocultures. Outside the FPD, some monotypic stands of western redcedar were also observed. The most common type of forest found outside the FPD is the mixed forest type (both deciduous and conifer species present). Currently, where stands of pure deciduous trees are present, they are dominated by either red alder or black cottonwood. Mixed stands were composed of varying combinations of Douglas-fir, western redcedar, bigleaf maple, red alder, black cottonwood, and occasionally Sitka spruce. A frequent hardwood species also encountered in mixed stands was bitter cherry.

9.5.1. Early-seral pioneers

The three main pioneering tree species occur in Newaukum Creek basin; Douglas-fir, red alder, and bigleaf maple. Douglas-fir is considered a fire 'resister ', whereas red alder is an 'invader' after a fire (Naiman et al. 1998). It is important to consider that forest regeneration does not typically begin from a 'clean slate' after disturbances in upland forests. Remnants from the previous forest still remain (e.g., snags, logs, and remnant trees; Franklin et al. 2002). These remnants can have important influences on the rate and trajectory of forest regeneration (see Franklin et al. (2002) for details.

Douglas-fir is the most fire-resistant species and is also the most common dominant colonizing species after a fire (Chappell et al. 2001). However, depending on seed sources and other

[55] Forest patches were mapped in GIS as part of the landcover shapefile (Appendix D), and forest type was assigned to each polygon by using a combination of field work (ground truthing) and high-definition color aerial photographs from 2005 and infrared images from 2002. 2002 landcover data from University of Washington was also used to aid in assigning forest type; however, this data only used two forest types (conifer and mixed/deciduous).

conditions, any of the dominant tree species in the Westside Lowlands Conifer-Hardwood Forest habitat type can re-establish after fire or other disturbance. After a fire, the canopy would begin to open up to allow ground story species to return by about 60-100 years of age, and eventually a multi-layered canopy will be formed by age 200-400 (Chappell et al. 2001). If no fire or other disturbance were to intervene, Douglas-fir trees could reach ages of 800-1,000 years.

Red alder is commonly the first tree species to establish after logging activities, but such is not the case in fire-disturbed areas (Franklin 1988). As a result, red alder stands are far more common under current conditions than they would have been historically. Nonetheless, a red alder stand will decline in importance (dominance) by age 70 and will typically completely die off by age 100 (Chappell et al. 2001). If conifer seedlings are present when the alder dies off, they may replace the alder stand, or if salmonberry has grown in thickly, it often precludes the establishment of conifer species (Franklin and Dyrness 1973).

Another species that responds well to logging and is therefore now relatively widespread is bigleaf maple (Chappell et al. 2001). Mature bigleaf maples are often the largest diameter tree with the greatest potential for providing near-term future habitat as snags in managed forests. Bigleaf maples also frequently have cavities, deep cracks and fissures, huge branches, and other features that provide cover and shelter for numerous species of wildlife.

9.5.2. Late-seral Canopy Dominants and Foundational Species

The Newaukum Creek basin lies within the Western Hemlock zone in the Puget Sound Area as defined by Franklin and Dyrness (1973). The Western Hemlock zone dominates most of Washington west of the Cascade Crest. Historically, western redcedar and western hemlock would have been present as late seral canopy dominants and foundational species in upland forests. Douglas-fir also would have been part of the forest, especially at higher elevations in the foothills (Table 1). According to Franklin and Dyrness (1973, pg. 55), “At the time of the first settlers, conifer stands clothed almost the entire area of western Washington…from ocean shore to timberline except for…some prairies in the Puget Sound trough.”

Deciduous species, primarily red alder and bigleaf maple, would have been uncommon and subordinate in upland forests except for disturbed sites. In the lowlands (on the Plateau), species found in undisturbed conditions would have included Sitka spruce along with bigleaf maple, black cottonwood, and red alder, though neither of the latter two species would dominate the canopy.

Western hemlock typically would live 400 years or more and attain diameters at breast height of 30-40 inches (75-100 cm) and heights of 82-118 ft (25-36 m). The amount of old-growth forest present in the basin at any given time, prior to Euro-American settlement, is uncertain. Notes taken during Government Land Office (GLO) surveys during 1872 and 1881 describe everything from thickets of young conifer trees to coming across Douglas-fir with 12 foot diameters. During the mid- to late-Nineteenth Century it appears that the forests of the Newaukum Creek basin were a patchwork of ages, and the varying ages were mainly the result of fires.

Douglas-fir is now the most common tree species found in the overstory of forest stands in the Newaukum Creek basin. Much of the zone has been logged, burned, or both, during the last 150 years, and Douglas-fir is the species that has been available for regeneration and planting. Thus, it is usually a dominant (often a sole dominant) tree in the stands that have developed after human disturbances (Munger 1930, 1940, as cited in Franklin and Dyrness 1973). In addition to Douglas-fir and western hemlock, other conifer species now present include western redcedar, Sitka spruce, and grand fir. Hardwood canopy species, dominated by red alder, bigleaf maple, and black cottonwood, are common in recently disturbed sites.

9.5.3. Snags

Snags and coarse woody debris (CWD) would have been an important component of every seral stage, even with most natural disturbances, with the possible exception of very high-intensity fires (Franklin et al. 2002). Peak abundance of coarse woody debris is in the first 50 years after a fire, and it is least abundant during stand ages of 100-200 years (Chappell et al. 2001). Large-diameter snags would have been present at varying densities. These snags provided nesting and denning opportunities for birds and mammals[56]. CWD would have been relatively abundant on forest floors, where it provides forage and nesting/denning opportunities for numerous species[57].

The forest that remains in the Upper Basin of Newaukum Creek, specifically in the FPD, is in private ownership and is managed for timber harvest. Snags, called Wildlife Reserve Trees, by the Forest Practices Rules are now required in WAC 222-30-020 to be left during timber operations; only 3 snags per acre >12 inches dbh are required by this WAC. However, the adoption of rules that regulated retaining snags first took place in 1992, so only stands harvested in the past 15 years have been subject to Wildlife Reserve Trees requirements. Almost no snags were observed during field visits to forests in the FPD portion of Newaukum Creek basin.

Snag density and CWD density is obviously well below historical levels in the Plateau. According to the DecAID model (Mellen et al. 2006) an average of 18.6 snags per acre over 10 inches (46 snags per ha over 25 cm in diameter (dbh) are needed to maintain the snag component at the 50 percent tolerance level for wildlife habitat[58]. Of those, 8.1 snags/acre (20/ha) should be larger than 20 inches (50 cm) dbh. These guidelines are conservative; at the 80 percent tolerance level, these densities should be doubled. The model also recommends managing areas for the complete range of snag densities and diameters to provide habitats for a variety of species. For example, to manage for all species at the 50 percent tolerance level, some snags as large as 57 in (145 cm) dbh should be provided for Pileated Woodpecker roost trees, and for all other species, snags from 32-39 in (80 to 100 cm) dbh should be present on the landscape.

In addition to snag numbers far below amounts recommended by the DecAID model and others over one century of forest management in the upper Newaukum basin has likely resulted in additional ecological consequences. Forests managed for timber production have greatly reduced function as wildlife habitat. These forests, which are typically on 50-year harvest rotations (but possibly as short as 35-year rotations), lack plant species diversity as well as structural diversity, including snags, trees with broken tops, and CWD. All of these are critical components of wildlife habitat in forests of the Pacific Northwest. Buffers should be present along qualifying streams in the FPD in areas logged after 1987 (the past 19 years) (see legislative changes in Section 5.0). Despite the variability of riparian management zones, it is

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[56] Species using snags include: spotted owls, barred owls, western screech owls, great-horned owls, pileated woodpeckers, various flycatcher species, kestrels, hawks, Vaux's swifts, martens, fishers, long-tailed weasels, raccoons, black bears, striped skunks, and various bat and myotis species.

[57] Shrews, voles, squirrels, foxes, bears, and skunks, winter wrens, song sparrows, and towhees.

[58] In DecAid, the tolerance level is the percent of observations of each wildlife species that correspond to particular sizes or amounts of snags and down wood. This can be interpreted as the level of "assurance" of providing for species' needs. We refer here to the managed forests in western Washington conifer-hardwood lowlands.

possible that with time the resulting corridors will re-establish the some of the structural diversity required for animal species diversity.

9.6. WILDLIFE COMMUNITIES

This section explains the general distribution and life history requirements of important wildlife (birds, mammals, reptiles and amphibians) in the Newaukum Creek basin. Summaries draw from the Washington Gap Analysis Program. Current wildlife communities reflect a long history of human activity, including land cover conversion and extensive road construction.

No formal surveys were conducted for any wildlife species. However, wildlife presence was assessed using the Washington Gap Analysis Program (WAGAP) data[59], which are supplemented by *Wildlife-Habitat Relationships in Washington and Oregon* (Johnson and O'Neil 2001)[60]. Table B2 in Appendix B summarizes the land cover identified in the Newaukum Creek Basin by WAGAP. This table represents a broad view of landcover groups present in the basin. These data are the foundation for the WAGAP species distributions discussed in this section. This habitat typing scheme was used in the analysis of wildlife species expected to be present in Newaukum basin. Discussions of both current and historic conditions will be based largely on 'wildlife habitat types' (Johnson and O'Neil 2001), which are based on the similarity of many wildlife species using a suite of vegetation types, and it is assumed that each type provides for all essential needs for a given species' maintenance and viability[61].

WAGAP data is generally representative of both breeding and non-breeding habitats of mammals, amphibians, and reptiles (hereafter, land animals), but not for migratory birds. Land animals may migrate or disperse to different habitat types or elevations, but generally speaking, these animals are more restricted to smaller ranges than birds. With a few exceptions- most of land animals do not migrate very far between breeding and non-breeding seasons. In contrast, some birds over-winter in the Newaukum Creek basin, then migrate north to breed. Therefore, overwintering species would be ignored if only WAGAP data were used to predict bird habitat. The following discussions are intended to capture habitat requirements for all the life histories of wildlife present in Newaukum Creek basin.

Current patterns of wildlife species abundance and distribution (including extirpation) in the Newaukum Creek Basin reflect the loss of large expanses of structurally diverse forests interrupted only by wetlands or streams and the increase of agricultural lands. The wide range of natural structural variability in the historical landscape provided cover, breeding habitat, food,

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[59] The WAGAP uses digital map overlays in a Geographic Information System (GIS) to "identify vegetation types, individual species, and species-rich areas that are unrepresented or underrepresented in existing biodiversity management areas" (WDFW 1999). The resulting land cover and vertebrate distribution maps are useful for our purposes. WAGAP landcover data are based on 1991 aerial imagery and therefore underrepresents the current extent of residential development near the City of Enumclaw. However, agricultural and forested areas are likely similar to 1991 levels.

[60] In the book *Wildlife-Habitat Relationships in Oregon and Washington* (Johnson and O'Neil 2001), 32 wildlife-habitat types are established and described. A wildlife-habitat type is a group of vegetation or land use/land cover types that are based on the similarity of wildlife use. Historically, these types would have been solely vegetation communities (as opposed to "land use" – for example, agricultural fields).

[61] Establishing the wildlife-habitat types included the selection of 541 native breeding species in Washington and Oregon and the subsequent identification of which of 119 classes of vegetative/land cover/marine types the species were found in. Statistical analyses were performed to establish species groupings with habitat associations (for methods, see O'Neil and Johnson 2001).

and water for many wildlife species. It is likely some of the same wildlife species are in Newaukum Creek Basin now as were present before the landscape was drastically altered by Euro-American settlement, but species' distributions and abundances would have been quite different from those of current conditions. Wildlife movement, migration, and dispersal routes are now affected by roads and vehicles, clearcutting, development, and by drained wetlands and channelized stream beds. Historically, the landscape would have been fragmented either by natural disturbance, such as fire, flooding, and insect and pathogen outbreaks, or by transitions in the native landscape from one habitat patch to another.

Road-building is widespread in Newaukum Creek basin, and this activity is potentially detrimental to wildlife populations. Strategies for mitigating transportation impacts should involve identifying important travel corridors for animal guilds (Jackson and Griffin 1998). For example, there are approximately 130 miles of road in Newaukum Creek Basin.

Roads are known to impact wildlife at the individual, local, and regional (population) scales (Forman et al. 2003; Sherwood et al. 2002). Animals are frequently struck and killed in vehicle collisions (e.g., amphibians, deer, reptiles) and roads have indirect impacts such as behavior modification, including altered home ranges or feeding behaviors (Trombulak and Frissell 2000). Roads can change the quality and quantity of adjacent habitat, and these changes can have both positive and negative effects on wildlife at the local scale. At the local scale, the density of animals and overall species richness tend to decrease with increasing proximity to a road as well and with road density. These relationships occur through a variety of factors, including direct mortality, avoidance, and disturbance (USDA 2000). Road maintenance can introduce a variety of herbicides, hydrocarbons, dust, and metals that negatively impact roadside aquatic habitats. The presence of roads and fragmented forests may facilitate the spread of bark beetles and fungi to areas that previously would have been relatively inaccessible (Trombulak and Frissell 2000; Perendes and Jones 2000). Alternatively, maintenance of roadside grass plant communities can provide dependable foraging habitat for raptors such as red-tailed hawks because of the small mammals that breed and live in them.

The impacts of roads on wildlife may be compounded at the landscape and population (or metapopulation) scale (see Jackson 2000). Population effects include the habitat isolation and fragmentation that separate individuals from each other and from access to critical habitats, hinder wildlife movement, and stop gene flow. Habitat connectivity can be reduced or eliminated for some wildlife species by roads. The extent of these impacts varies by species and animal guild: roads can present complete barriers to low-mobility species such as reptiles, amphibians, and invertebrates (Forman et al. 2003), whereas they may pose no barrier to raptors. Amphibians may be one of the most vulnerable groups of species that crosses roads. It is unknown whether there are annual amphibian migrations that are impacted by roads in the Newaukum Creek basin.

9.6.1. Birds

Approximately 114 bird species may breed in the Newaukum Creek basin based on Washington Gap Analysis (WAGAP) of 1991 landcover data. According to the Breeding Bird Atlas (BBA) for King County (Opperman et al. 2006), 106 species are possible, probable, or confirmed breeders in the 10 survey blocks that encompass (and extend beyond) the boundaries of Newaukum Creek Basin (see Appendix E, Table E1 for data set). These sources strongly overlap, though

WAGAP predicts 12 species that BBA does not report, and BBA reports 4 species that WAGAP does not. These potential breeding birds are all listed in Appendix E; Table E2).

Perhaps the most valuable habitat remaining in the basin for many species of birds is the naturally vegetated and open-water wetlands and the naturally vegetated riparian zones[62]. These areas provide foraging and nesting habitat for warblers, sparrows, shorebirds, vireos, wrens, flycatchers, blackbirds, ducks, and others. Additionally, wetlands provide forage and cover for many species that overwinter in Puget Sound, including song and fox sparrows, ruby-crowned and golden-crowned kinglets, black-capped and chestnut-backed chickadees, Bewick's and winter wrens, spotted towhees, juncos, Steller's jays, downy and hairy woodpeckers, and great-blue and green herons.

The extensive agricultural lands in Newaukum Creek basin likely provide increased amount of foraging habitat for species that use open areas and meadows, and as such their populations may be higher in Newaukum Creek basin than they were historically. These species include raptors such as the Northern Harrier, American Kestrel, and Red-tailed hawk. In fact, each of these species were observed during field work. For species such as the American Kestrel, which is a cavity nesting bird, their limiting factor in the basin may be adequate nesting cavities in snags. Red-tailed hawk is a year-round resident in King County (Section 9.1.).

Bird abundance and richness of forest interior bird species has likely decreased in communities within the forest interior, but richness has likely increased in communities that thrive in open or disturbed conditions. Current conditions may actually enabled a net gain in species richness, because few species have been extirpated, though populations are often reduced; the ecotones associated with the introduction of farmland and agricultural areas offer additional habitat types for new species to utilize.

Some guesswork is required to ascertain which birds were once abundant but are now scarce in the Newaukum Creek basin. We can use the example of wetlands to examine some of the potential changes that have occurred in bird species composition in the basin. It is unknown how much of the historic wetlands were lacustrine, palustrine, and riverine. Moreover, it is unknown what proportions of the historic wetlands were characterized by open water, how much were forested, and how much were scrub-shrub or emergent habitat types. Nonetheless, some broad generalizations are justifiable given certain assumptions. For example, if only 5 percent of the 6,445 acres (see Section 7.3) were open-water, that would be 322 acres of open water. This conservative estimate dwarfs the current area of 26 acres. Additionally, because beavers were present and building dams, the amount of open water would have been increased by their presence and thus provided habitat for many species of waterfowl and shorebirds, including great blue herons, American bitterns, and songbird species such as warblers and wrens. Wood ducks would have had a vast supply of snags in which to build their nests. It is speculated that great blue heron colonies would have likely been more abundant than at present, and osprey would have had ample trees and large snags for nesting, because the areas surrounding the wetlands would have been forested.

Approximately 5,202 acres of forest habitat are present within the basin, but very little of it has the mature forest structure and snags that woodpeckers require for foraging and breeding habitat. Given the appropriate conditions, up to five species of woodpeckers (northern flicker, pileated woodpecker, downy woodpecker, hairy woodpecker, and red-breasted sapsucker) may be present in the basin. Historically, snag would have been pervasive: in most forests,

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[62] Old fields and woodlots may also be important, for different reasons.

regardless of age, as well as most types of wetlands (see details in Section 9.5.3). Snags provide habitat for primary excavators, including woodpecker, nuthatch, and chickadee species. Those primary cavity builders are responsible for creating habitat for a large array of secondary cavity users, including fisher, marten, flying squirrel, common merganser, wood duck, American kestrel, and various species of bats, swifts, swallows, and owls.

9.6.2. Mammals

Fifty-seven mammal species are predicted to breed in the Newaukum Creek basin (Appendix E, Table E3), according to Washington Gap Analysis (WAGAP), which relied on 1991 landcover data. Perhaps the single most important change from historical conditions is a decline in beaver populations.

We speculate that beavers (and muskrat) were once highly abundant, given the large, flat geography of the Plateau and evidence from surveyors notes (ca. 1800s). However, beaver and likely muskrat are now expected to have very limited distribution in Newaukum Creek basin. Beavers are considered ‘ecological engineers’, or ‘keystone species’ because they control hydrology, and thus their environment, (including sediment routing, nutrient cycling, and riparian forest composition) through construction of dam complexes. Resulting beaver ponds raise water depths and back up water. These waters inundate riparian habitats to form wetlands, and snags are often created from the forests that were flooded. Snags in wetland areas provide habitat for many cavity-nesting species, including swallow species and purple martins, as well as raptors that require large snags for their nests, such as osprey. Beavers are also considered an ‘umbrella species,’ because their protection favors the preservation of a whole series of other plants and animals with similar or related habitat requirements.

Forests of the Upper Basin (including the FPD) likely provide habitat for small mammals, including squirrels, shrews, voles, and mice. These small mammals provide an important prey base for predators such as bobcat and weasels, as well as raptors such as Cooper’s Hawks and owls. However, the forest in the FPD is nearly all second- or third-growth Douglas-fir in a monoculture that lacks structural diversity, snags, and CWD, all of which are important wildlife habitat components (see Section 9.5.2). The lack of structural diversity results in reduced native mammalian species diversity and shifts in abundance.

The loss of old-growth forest in the basin equates to a loss or reduction of marten, fisher, and Townsend’s big-eared bats, all of which require old-growth trees for breeding habitat. According to WAGAP, nine bat species are expected to breed in the basin, provided that their required habitat is available. Three of these species (Townsend’s big-eared bat, long-eared myotis, and long-legged myotis) are species of special status (see Table 7, Section 9.1.). Bats generally display similar reproduction, foraging, and hibernation behavior, with some variations (Ingles 1965, Christy and West 1993). Foraging habitat varies between species of bats, but all species use open water and riparian edges (Ingles 1965, Burt and Grossenheider 1980). Breeding females and juveniles often roost communally in large natural or man-made cavities and crevices with constant temperature and humidity.

Large herbivores, including Black-tailed deer *Odocoileus hemonius* and Rocky Mountain elk *Cervus canadiensis* use the basin to varying degrees. Their populations likely fluctuated historically depending on disturbances such as forest fires that affected forest age and structure. Generally speaking, deer are primarily browsers, fulfill their cover and food requirements from shrubs in forested areas, whereas elk are seasonal grazers, foraging on herbaceous vegetation in clearcuts and open areas to a greater extent. Both species use riparian areas and wetlands for their water needs (Witmer et al. 1985). Both of these ungulates also often calve in riparian areas, where the young feed on emergents and other herbaceous riparian and wetland species.

Forage areas for elk and deer are defined as “vegetated areas with less than 60 percent combined canopy closure of trees and shrubs taller than 7 feet” (Witmer et al. 1985). Clearcut areas provide a high amount of understory forage; however, as a new forest begins to regrow, the forage habitat declines steeply. Also as the new forest regenerates, the potential for hiding cover increases. Optimal hiding cover screens 90 percent of a standing adult deer or at 200 feet or less distance (adapted from Thomas et al. 1979). However, thermal cover (insulation from fluctuating temperatures) may not be present until the stand is exhibiting characteristics of a mature forest. Thermal cover is defined as a forest stand that is at least 40 feet in height with tree canopy of at least 70 percent (Witmer et al. 1985). Based on these definitions, a mix of habitats where forage is adjacent to dense tree and shrub cover is ideal for black-tailed deer and elk. Old-growth habitat is preferred over adjacent second-growth habitat in both winter and summer by deer and elk (Janz 1980; Pedersen et al. 1980; Witmer 1981; Hanley 1982; all as cited in Witmer et al. 1985). The Upper Basin in Newaukum Creek basin is used by deer and elk, but the habitat is considered suboptimal. Further, these ungulates would have occupied habitat throughout the entire basin historically, when forests and wetlands covered the Plateau. Deer still use the Plateau, but available cover habitat is limited.

Coyotes *Canis latrans* are present and common in most of Washington. Historically, coyotes likely would have been restricted primarily to the brushy mountain areas of Newaukum Creek basin because wolves *Canis lupus* occupied the forests. With the removal of gray wolves from the region, coyotes have been able to expand their range. They prefer open habitat and forest edges and readily use open forests and extensive burned or clear cut areas. They are found in agricultural lands and at the edges (and sometimes into) developed areas. Coyotes are adaptive enough that they appear to be maintaining their numbers and are possibly increasing in some areas.

Two large predators, grizzly bears and gray wolves, are now absent from the Newaukum Creek basin. Where they exist, these predators not only affected their prey populations, they also perform the key ecological function of providing carrion for other wildlife species such as fisher, mink, weasel, and skunks. The loss of grizzly bears and wolves equates to the removal of the largest predators in the area, and the reduction of predators has implications for other animal species. Historically, smaller predators, including marten, fisher, mink, and weasels would not have been uncommon. Additionally, because these species provided carrion, other predators that use carrion might be affected by their extirpation (Johnson and O’Neil 2001, pg. 178). However, coyote *Canis latrans*, bobcat *Lynx rufus*, black bear *Ursus americanus*, and cougar *Felis concolor* are still present in the basin. These predators may fill niches left vacant by the other large predators.

Cougars, also known as mountain lions, are almost exclusively carnivorous. Cougars generally prefer open or mixed forest and shrubby cover types with an abundance of prey. They feed primarily on ungulates (deer and elk), and they will also feed on a variety of smaller mammals, including porcupines, rabbits, beaver, ground squirrels (*Spermophilus* spp.), marmots (*Marmota* spp.), and other small rodents (Dixon 1982; Lindzey 1987; both as cited in Witmer 1998). Cougar occupy large home ranges from 12 to 400 square miles (Dixon 1982; Lindzey 1987; Seidensticker et al. 1973; all as cited in Witmer et al. 1998). Because it is likely that prey are not as abundant in the managed forests of the FPD, cougar home ranges in Newaukum Creek basin and surrounding areas are likely on the higher end of the range.

Bobcats are found where there is cover such as forests, thickets, wetlands, and agricultural areas. In summer, they may be found in high-elevation forests but are driven to lower altitudes by winter snow. They are expected to be present in varying densities throughout the Newaukum Creek basin.

The other large mammal that remains extant in the Newaukum Creek basin is the black bear. Black bears are omnivorous, and their food sources may include the cambium layer of trees, insects, carrion, livestock, deer fawns, and garbage. Plant matter makes up most of their diet, with grasses, sedges, forbs, and berries selected based on seasonal and spatial availability (Kolenosky and Strathearn 1987; Pelton 1982; both as cited in Witmer et al. 1998). Their preferred habitat is a mix of forest and open areas. Black bear also occupy large home ranges: from 4 to 40 square miles (Kolenosky and Strathearn 1987; Pelton 1982; both as cited in Witmer et al. 1998). The FPD in Newaukum Creek Basin lacks meadow areas as well as many types of vegetation black bears prefer. However, blackberry shrubs are common and likely augment their diet. The lack of denning sites often associated with old-growth forest may be a limiting factor for black bear populations in the Newaukum Creek basin.

Black bear and cougar “nuisance reports” are filed with WDFW when they occur. Frequently these reports are filed with a collision with a car or some other personal property damage has occurred, so these sightings do not indicate the range of these two species in the basin. Rather, they might be more indicative of where their ranges most frequently intersect with humans in the basin. Black bears are reported more frequently than cougars. Bears have been reported in the ravine near the mouth of the Green River. Both species have been reported at the eastern end of the Plateau; it is possible that these bears and cougars were exploring beyond the FPD, where they likely originated.

9.6.3. Amphibians and Reptiles

Washington Gap Analysis (WAGAP) used 1991 landcover data to predict approximately 17 amphibians and reptiles (herptiles, collectively) that may be present in Newaukum Creek basin (Appendix E, Table E4). Unlike bird species, herptile diversity would have been greater historically, because 1) the interdependent habitat components they require for survival would have been more common; and 2) no non-native species were present to compete with the native fauna. The distribution and abundance of native lentic, lotic and terrestrial breeding amphibian species was likely greater historically.

The western pond turtle would have possibly been found along the shorelines of ponds in the basin. This species has likely been extirpated from the basin, and throughout most of its historic range in the Puget Sound Ecoregion. According to the Washington Herp Atlas, “The major threats to this species are: (1) loss of hatchlings to bullfrogs, (2) alteration of important features of aquatic or terrestrial habitats, (3) loss of nests to human activities or predators, (4) disease and competition from introduced turtles, and (5) removal from the wild by humans.” Painted turtles are presumed to have been introduced into the Puget Sound ecoregion, and it is now naturalized. The first records in King County are in the 1960s, so it is presumed that this species was either not present historically at all in Newaukum Creek Basin, or if it was present, it was not as widely dispersed as they are currently.

Several of our more upland garter snake species may have expanded their ranges and numbers in conjunction with increased clearing and human habitation; whereas the species associated with aquatic habitat types may have declined. Rubber boas may have been more widely distributed prior to extensive forest and agricultural practices; however, little is known about their population trends or even their current status because, according to the Washington Herp Atlas, “(1) it is difficult to find nocturnal, semi-fossorial snakes, (2) the records are primarily from opportunistic encounters and not systematic surveys, and (3) they occupy a variety of habitat types suggesting they are able to adapt to a variety of habitat conditions.” Human disturbance has most likely decreased the distribution and abundance of Northern alligator lizards from historic conditions.

Amphibian species may have been more abundant and widely dispersed prior to habitat conversion, destruction and fragmentation. Terrestrial-breeding salamanders, especially those associated with mature and old-growth forests may have been more abundant and ranged more widely across the Puget Sound Trough than indicated by their present distribution. Stream-breeding species such as tailed frogs and Pacific giant salamanders have decreased in range and abundance with clear-cut and burn timber practices, land clearing and conversion to agricultural uses. These species are sensitive to stream temperature increases, sedimentation and other disturbances. Wetland-breeding species such as Oregon spotted frog, Northern red-legged frog, and western toad may have had greater distributions prior to extensive clearing of forests, conversion of land cover, disturbance to lakes and ponds, habitat fragmentation and the introduction of non-native fish, amphibians and other species.

Currently, the lack of permanent open water wetlands suggests that turtles, Northwestern Salamander, and American bullfrogs (non-native) are unlikely permanent residents in the basin, although permanently flowing ditches could be used by either of the amphibian. Seasonally flooded wetlands would provide breeding habitat for the remainder of the amphibians listed Table E4 (Appendix E), as well as foraging habitat for all garter snakes. Nearly all wetlands in the basin are found on the Plateau (99% of wetland area). Except in the case of some open-water ponds (most of which are agricultural ponds), most of the wetlands on agricultural fields are expected to dry out seasonally. Permanent and seasonal water sources are essential for the reproductive life stage of all aquatic-breeding amphibians (Nussbaum et al. 1983, Leonard et al. 1993). The forested wetlands on the plateau may be used for breeding, particularly for lentic[63]-breeding species such as northwestern salamander, roughskin newt, northern red-legged frog, and Pacific tree frog (Richter and Azous 2001). Newaukum Creek may provide habitat for lotic-breeding (stream-breeding) amphibians such as the giant salamander (Richter and Azous 2001).

Upland areas surrounding wetlands are also important habitats for amphibians and reptiles. Richter and Azous (2001) report that amphibian richness in 19 surveyed palustrine wetlands around Puget Sound was highest in wetlands that retained at least 60% of adjacent area in forest up to and exceeding 1,500 feet from the wetland. Approximately 9 wetlands in Newaukum Creek basin satisfy these criteria, and these wetlands are all in the Upper Basin. However, these wetlands appear to be either forested or open water ponds lacking emergent vegetation. Three of them may be emergent wetlands that potentially lack open-water, or if there is open water present, the amount of native amphibian habitat is extremely limited.

9.6.4. Arthropods

A detailed characterization of terrestrial and riparian arthropods exceeds the scope of this report, but we wish to acknowledge the importance of these organisms to ecosystem function, and as prey supporting the productivity of other consumers.

9.6.5. Non-native Wildlife

Non-native species introductions began with the arrival of Euro-Americans beginning around the mid-1800s. During the late 1800s, the diversity, abundance, and subsequent effects of non-

[63] Slow-moving or stationary water, such as ponds.

native species would have been in their infancy, and some non-natives would not have been present until well into the 1900s. Table E5 (Appendix E) summarizes the non-native species that have been introduced into the Newaukum Creek Basin in the past 150-200 years, as well as their effects on the native flora and fauna.

The list in Appendix E is not a comprehensive list of all non-native animals in the region, but identifies those with the greatest potential to do the most harm to native wildlife species. The European Starling is one example of an invasive non-native species. It has become one of the most numerous bird species in the United States, and their aggressive ability to out-compete native birds for nest cavities becomes problematic in areas where cavities are scarce (Witmer and Lewis 2001). In the Newaukum Creek basin, they would be likely have the greatest impact on woodpecker species and cavity-nesting ducks (Ingold 1994, 1996; Welsh and Howard 1983).

10. CONCLUSIONS

The findings in this report can be used to underpin a comprehensive set of management objectives that reflect unique aspects of the Newaukum Creek Basin and are consistent with the existing priorities set by the Salmon Habitat Plan for the Duwamish/Green River (WRIA 9 Planning Committee, 2005). Further study is needed to address several major data gaps listed below. Addressing these and other uncertainties will be a valuable next step to reduce uncertainty in the outcome of future restoration projects. In the meantime, we propose a simple set of recommendations for consideration in future planning efforts.

10.1. ECOLOGICAL ALTERATIONS IN NEWAUKUM CREEK BASIN

Current conditions in Newaukum Creek appear to be affected by a number of ecological alterations, listed below in no particular order. This is a partial list of the factors warranting consideration in plans to improve habitat conditions in the basin.

Low flow conditions are growing more extreme. The observed low flow rate (annual minimum 7-day mean flow) is declining at a rate of 0.12 cfs per year.

Streamflows are flashier, floods are more frequent than under historic conditions. Model simulations compared the historic ‘forested’ conditions with the ‘current’ developed condition of the basin, holding climate constant. Results suggest that flood events are now more frequent. For example, if Newaukum Creek Basin was completely forested, flows of 800 cfs would occur once every 10 years, whereas under ‘current’ conditions this flow occurs once every three years.

Peak annual flow magnitude is declining. Observed peak annual flow rates in Newaukum Creek declined at a rate of 5.4 cfs per year over the 60-year period of record, despite increases in impervious area and reductions in forest cover, meadows, and wetlands. Declines in peak flows may reflect both climatic change and impacts from human activities in the basin.

Surface and groundwater hydrology have likely been altered by growth of impervious surfaces. Impervious areas now cover 11% of the Newaukum Creek Basin, ranging from 2 to 59% among sub-basins. Model simulations suggest that forested areas show the least amount of hydrologic change from historic conditions. Areas with the highest amount of impervious surfaces show the greatest degree of change. Increases in the frequency of 10-year floods range from less than 10% to over 200% across the basin. Groundwater hydrology may be altered by landcover changes, as well as three large public water systems for domestic use (including two major springs) and 82 smaller public water systems that are almost entirely supported by wells. Personal wells for irrigation and livestock watering are common but poorly quantified.

Humans have created roughly 77 miles of artificial channels and reduced wetland area by at least 80%. These changes are largely attributable to extensive dredging, diking, draining, and ditching. Near the confluence with the Green River, Newaukum Creek has been locally straightened, armored and confined by berms, and large wood was historically removed. Additional factors contributing to wetland loss likely include declines in the number of beavers in the system and the introduction of reed canarygrass to improve land for cultivating agricultural crops.

Removal of riparian forests from most of the Plateau has likely exacerbated high stream temperatures, simplified stream channels, and encouraged the spread of non-native species. Loss of insulating shade from trees increases the heat load to the stream. Forest removal has also depleted the supply of trees that could otherwise fall into the channel and create pools and complex habitats. Impacts also extend to wildlife, which use riparian areas (and wetlands) extensively. Non-native species, such as reed canarygrass and Himalayan blackberry capitalize on harsh conditions resulting from forest removal. These species often exclude native plants and wildlife and may artificially stabilize streambanks and simplify the channel.

Water quality appears to have improved, but remains degraded. Water temperatures– specifically, the 7-day average daily maximum – in most portions of the mainstem and tributaries of Newaukum Creek consistently exceeded Washington state standards for spawning and incubation habitat as well as core summer salmonid habitat. The only locations that largely met standards for cool water were in Big Spring Creek and in the mainstem just below the forested headwaters. Stream temperature problems may be attributed to human activities that increase the heat load to the stream or reduce stream discharge. Factors can be ranked in order of increasing importance; (1) losses in riparian shade from forest clearing; (2) alterations to groundwater; (3) warming or reduced discharge in tributaries; (4) declines in mainstem discharge; and (5) reduced buffering from groundwater. Simulations suggest that nitrogen concentrations are elevated in the wet season, whereas phosphorous concentrations are elevated during the dry season, because of the relative contribution of groundwater to streamflows. Elevated phosphorus concentrations are likely from surface runoff from pastures during storms. Observed concentrations of bacteria are variable. Bacterial concentrations are higher in spring and fall when storms are large and infrequent, allowing fecal matter to accumulate on the landscape between storms. In summer, storms are small and infrequent; low, variable concentrations during this period are likely a result of animal activity with low potential runoff.

Conversion of native forests to plantations has reduced the structural habitat complexity of forest wildlife and the availability of snags and downed logs for nesting and feeding habitat. Most of the Upper Basin has been converted from natural forests to a high-yield (Douglas-fir) forestry plantation and fires are actively suppressed. Plantation forests have greatly reduced function as wildlife habitat, as snags, downed logs, and trees with broken tops or stands with multilayered canopies are relatively rare. Red alder stands and bigleaf maple are now far more common than they would have been historically.

Landcover changes and fragmentation may have benefited some birds, but have generally resulted in widespread loss of wildlife habitat. The extensive agricultural lands in Newaukum Creek Basin likely provide an increased amount of foraging habitat for species that use open areas and meadows. In contrast, the abundance and richness of bird species has likely decreased within the forest interior. The lack of structural diversity in forests of the Upper Basin likely reduces the diversity and abundance of native mammals. Amphibian species may have been more abundant and widely dispersed prior to habitat conversion, destruction and fragmentation. Road-building is widespread, and this activity is potentially detrimental to wildlife populations because of collisions, altered home ranges or feeding behaviors, and reduced gene flow.

10.2. MAJOR KNOWLEDGE GAPS

Agencies and landowners both possess considerable but incomplete knowledge of the streams, lands, and wildlife in the Newaukum Creek Basin. This report is not without substantial limitations, omissions, and speculations. Knowledge of the basin's ecological systems will evolve and improve by coupling scientifically robust studies with the local knowledge and long-term perspective of people that live and work in the basin. Further investigation is warranted on many topics, including the following:

- Mechanistic explanations for declines in peak flows and annual low flow levels.
- Cumulative effects of water withdrawals for irrigation, livestock watering, and domestic use on summer low-flow conditions.
- Spatially continuous evaluation of heat load and discharge in the mainstem to explain and correct exceedingly warm stream temperatures.
- Map of areas that lack fences to prevent livestock from damaging stream banks and better understanding of the potential instream consequences and effects on riparian vegetation.
- Life history, distribution, and productivity of Chinook salmon and steelhead trout using Newaukum Creek for spawning and rearing (for example, is a yearling life history form of Chinook salmon present?).
- Continuous surveys of fish distribution during spawning and rearing, as well as data on the variation in the distribution of spawning over time.
- Comprehensive assessment of road crossings to identify potential barriers to juvenile and adult fish migrations (currently underway).
- Better understanding of non-native plant and animal species distributions within Newaukum Creek Basin and their potential impacts on native plants and wildlife.
- Detailed studies of current water quality conditions, including fecal bacteria loadings, and the identification of ongoing sources of water quality degradation.

10.3. ANTICIPATING FUTURE CHANGE

Restoring and maintaining productive habitats for plants, fish, and wildlife in Newaukum Creek warrants consideration of the legacy of human impacts and present conditions, but also the anticipated future. Substantial uncertainty remains, but it is important to 'look before we leap'. This is accomplished by explicitly addressing potential consequences of future changes when planning management strategies.

More people in cities and rural areas: Human population growth and increasing development within the Urban Growth Area and in rural areas around the City of Enumclaw is expected to exacerbate existing ecological impairments and further constrain restoration opportunities in the basin. In particular, further development and related land use change may affect streamflow and water quality parameters and the extent and fragmentation of forested habitats.

Warmer stream temperatures from altered hydrology: Mean annual temperatures in the Newaukum Creek Basin are expected to rise in the future, and such a rise would exacerbate water quality problems in the basin. Results from model simulations suggest stream temperatures are likely to increase as a result of diminished groundwater base flows. Conversely, summer stream temperatures could be improved beyond existing conditions by increasing the riparian shade (e.g., in a forested stream system). Impacts of regional warming trends in air temperatures on stream temperature were not considered here, but may further exacerbate existing problems.

Slightly larger, more frequent floods and lower summer flows from regional warming trends: Streamflows in Newaukum Creek may be affected by regional warming trends. Six percent of the Newaukum Creek Basin receives seasonal snowfall (for example, where elevation exceeds 1,500 feet). Increases in air temperature cause more snow to fall as rain. Storms that drop rain on existing snowpacks (i.e., rain-on-snow events) will likely become more frequent in these areas. An increase in these events would amplify the annual number of storm run-off events, which also affect downstream areas along the stream. Moreover, higher elevations that would normally retain snow cover through May or June will lose their snowpack earlier in the year, causing higher spring flows and lower summer flows. Landcover change alone is not predicted to change flows drastically from current conditions, because agricultural land with naturally impervious soils will continue to be the dominant land cover type. Anticipated differences between current and future conditions are minimal, because the existing landscape is mostly ‘built out’ and increases in impervious area are expected to occur in zones that are already impacted by development.

Findings in this report can be used to support a comprehensive set of management objectives that reflect unique aspects of the basin and are consistent with the existing priorities set by the Salmon Habitat Plan for the Duwamish/Green River (WRIA 9 Planning Committee, 2005). Further study is needed to address the knowledge gaps listed above. Resolving these and other uncertainties require community partnerships. This will be a valuable next step to reduce uncertainty in the outcome of future restoration projects. In the meantime, management priorities and habitat improvements should be consistent with general themes outlined in Section 10.4.

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10.4. INTERIM CONSIDERATIONS

Identifying and prioritizing specific habitat improvement projects within Newaukum Creek Basin exceeds the scope of this report. Such an effort will require further study to characterize specific locations in detail. Input from key stakeholders in the basin will also be needed. Management priorities and habitat improvements should be consistent with the following themes:

Restoration actions in the alluvial fan reach near the base of Boise Ridge and in the Ravine should allow for lateral migration and channel switching. Channel change is particularly important in these areas, whereas the stream is relatively stable across the Plateau.

Restoration actions should support the productivity of existing juvenile Chinook and create opportunities in Newaukum Creek for the re-establishment of historic life-history diversity. For example, projects which promote greater abundances of the nearly extirpated ‘yearling’ (stream-type) juveniles. Stream type juveniles depend most heavily on the quality of freshwater rearing habitat, such as that provided by Newaukum Creek.

Restoration actions across the Plateau (and elsewhere) may benefit from allowing keystone species (beavers, for example) to create and maintain productive habitats. Likewise, enhancement of salmon populations may have far-reaching benefits. Spawning salmon are potentially important in supporting the productivity of stream and riparian plants and wildlife in the basin.

Fish abundance can be expected to vary within Newaukum Creek Basin – both among small tributaries, and along the mainstem between years. Fish production is naturally variable. Stable populations are often the exception, rather than the rule. These fluctuations may increase the resilience of the aquatic community and may prevent any one species from exploiting stream resources to the detriment of the others.

Restoration actions should consider terrestrial, riparian, and stream habitats – they are connected by flows of water, sediments, nutrients, and organic matter. In many ways, the riparian zone can be considered fish habitat; from this perspective, fishless streams are inseparable from fish-bearing rivers downstream (Naiman and Latterell 2005). Thus, the condition of the Ravine and Plateau is materially linked to the condition of streams and forests in the Upper Basin, whether or not fish are present in the headwaters.

Riparian restoration efforts will be important in reducing heat load to streams, but improving summer-low flow conditions should be coupled with reforestation efforts. Riparian plantings should capitalize on the natural patterns of vegetation succession (Franklin et al. 2002). To ensure additional benefits for wildlife, strategies should address not only the linear extent of riparian forests, but also forest structure: live trees, dead trees, large diameter trees, lower canopy tree community, ground community, downed logs, rootwads, vertical distribution of canopy, and gaps.

Habitat assessments (and corrective actions) should address the implications of climate change predictions for the Pacific Northwest. Strategies should also be linked across spatial scales because benefits from habitat improvements (like problems from stream degradation) can extend both upstream and downstream (Fausch et al. 2002).